Interagency Ecological Program

COOPERATIVE ECOLOGICAL
INVESTIGATIONS SINCE 1970

Background Information for the 2001 Review

of the

IEP Environmental Monitoring Program

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PROGRAM OVERVIEW

The Environmental Monitoring Program (EMP) for the Sacramento-San Joaquin Delta, Suisun Bay, and San Pablo Bay is conducted under the auspices of the Interagency Ecological Program (IEP). The EMP was initiated in 1971 in compliance with California State Water Resources Control Board Water Right Decision D-1379. Currently it is mandated by Water Right Decision D-1641. The program is carried out jointly by the two water right permittees operating the California water projects, the United States Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR). Assistance is provided by the California Department of Fish and Game (DFG) and the United States Geological Survey (USGS). The primary purpose of the IEP EMP is to provide necessary information for compliance with flow-related water quality standards specified in the water right permits. In addition, the EMP also provides information on a wide range of chemical, physical and biological baseline parameters. Discrete baseline samples are collected monthly from 11 sites in nine regions of the Delta using a research vessel and a laboratory van. Several constituents are also measured continuously at seven stations. Stations listed as "continuous recorder sites" in D-1641 are not part of the EMP. While some discrete sample processing is completed on board, most sample analyses are conducted by the Department of Water Resources Bryte Chemical Laboratory. The resulting data is entered in the DWR Field and Laboratory Information System (FLIMS). From there, it is transferred into the new IEP relational database and the DWR Water Data Library. Continuous data is available on a near real-time basis on-line through the IEP Hydrologic Engineering Center Data Storage System (HEC-DSS) Time-Series Database. Monitoring results are analyzed and summarized in annual and occasional multi-year reports and in brief updates in the IEP newsletter. Currently, the EMP has a total budget of close to three million dollars and up to 20 full and part time employees.

In the 30 years of its existence, the IEP EMP design has remained relatively unchanged. The greatest revisions came about in 1978 with the enactment of Water Right Decision D-1485 and after a major review of the program in 1995. The main goal of the 1995 revision was to streamline the existing program for more efficient budget and resource allocation. In consequence, discrete baseline sampling stations were reduced from 26 to 11 sites and contaminants monitoring was discontinued.

This document provides background information for the 2001 review of the IEP EMP. It summarizes the program's history, previous reviews and revisions, and its current resources, budget, and staffing. The legal history of the program is reviewed in more detail in Appendix 1. Appendix 2 describes the current EMP design. References relevant to the EMP are listed in Appendix 3. The reference list includes books, reports, journal articles and online resources.

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I. Introduction

A. The IEP Environmental Monitoring Program

This document describes the history and present state of the Interagency Ecological Program's Environmental Monitoring Program (IEP EMP) for the Sacramento-San Joaquin Delta, San Pablo Bay, and Suisun Bay in California. The IEP EMP was initiated in 1971 in compliance with California State Water Resources Control Board Water Right Decision D-1379. The program is carried out jointly by the two water right permittees, the United States Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR). Assistance is provided by the California Department of Fish and Game (DFG) and the United States Geological Survey (USGS) under the interagency framework of IEP. During the three decades of its existence this program has been referred to in various ways, *e.g.* "DWR Compliance Monitoring Program," "D-1485 Monitoring," "Water Quality Compliance Module of the IEP Monitoring Program," "Compliance Water Quality, Phytoplankton, Zooplankton, Benthic Monitoring," etc. The name "Environmental Monitoring Program" was first suggested in SWRCB Publication No. 40 of 1970. This publication contained a monitoring plan developed by the Stanford Research Institute. Much of this plan was incorporated into the IEP EMP. However, the name was only occasionally used. The IEP EMP described here monitors water quality, phytoplankton, zooplankton, and benthic organisms through boat and van sampling and a network of seven continuously recording multi-parameter shore stations. It does not include monitoring at any other continuous recorder sites listed in the most recent water right decision (D-1641). The main purpose of the IEP EMP is to provide information about the impacts of river flow regulation and water diversions on water quality so that water quality standards specified in California Water Quality Control Plans and Water Right Decisions are maintained. Flow regulation is necessary for flood control, power generation, and to provide the California State Water Project (SWP) operated by DWR and the federal Central Valley Project (CVP) operated by USBR with steady, predictable amounts of fresh water for export to agricultural, municipal, and industrial water users.

The latest IEP guidelines and the current Water Right Decision D-1641 require revisions of the IEP EMP at regular intervals in response to changing environmental conditions and new knowledge about the system. To date, the IEP EMP has undergone two major revisions via the State Water Resources Control Board (SWRCB) water rights hearing process. This document provides background information to facilitate the programmatic review of the IEP EMP scheduled for 2001. It contains a brief history of the program including information on its origins and objectives and the evolution of sampling stations and measured parameters. It also describes previous program reviews and current program resources. Detailed information about the legal aspects of the program as well as its current sampling and analytical design can be found in the appendices. Information about the 2001 review process is provided in a separate document.

B. Setting

The San Francisco Estuary is situated in central California and is the largest estuary in California (Fig. 1). It consists of a chain of bays to the west of the Coastal Range with a single connection to the Pacific Ocean via central San Francisco Bay through the Golden Gate. The estuary also includes brackish Suisun Bay and Suisun Marsh and the fresh-water Delta to the east of the Coastal Range at the confluence of the Sacramento and San Joaquin Rivers. The IEP EMP monitors water quality at 16 sites in the Delta and 12 sites in Suisun Bay and San Pablo Bay. San Francisco Bay water quality is monitored by other programs (mainly the USGS, s. http://sfbay.wr.usgs.gov/access/wqdata/, and the San Francisco Estuary Institute, s. http://www.sfei.org/rmp/index.html).

Fig. 1: Geography of the San Francisco Estuary (graphic design: CALFED)

The Delta drains about 37 % of the state of California and covers an area of 738,000 acres with more than 700 miles of natural and man-made waterways interspersed by farmed "islands." The Delta receives average yearly inflows of 24 million acre feet. A considerable amount of Delta water is exported by approximately 7000 diverters for agricultural, urban, and industrial uses. The largest of these diverters, the California State Water Project (SWP) and the federal Central Valley Project (CVP), draw an average of 5.9 million acre feet per year. These water uses compete with water needs of over 400 plant, 225 bird, 52 mammal, 22 reptile and amphibian, and 54 fish species in the Delta. Before the reclamation of the Delta islands in the 19th century, the Delta consisted of vast tidal and seasonal wetlands. Today, 8,000 of the original 345,000 acres of tidal marsh remain in the Delta with the majority of marshland located in Suisun Marsh. Over 52,000 acres of the Delta are under cultivation.

In recent years, the estuary has been the focus of unprecedented state and federal restoration and conservation efforts to address the conflicting needs and uses. These efforts culminated in the establishment of the CALFED Bay-Delta Program, a cooperative effort by state and federal agencies including the IEP agencies, in 1994. While the IEP and its Environmental Monitoring Program are currently not formally part of CALFED, they provide much of the information base needed for the design and implementation of many CALFED projects. However, the primary mandated purpose of the IEP EMP is to provide information about the effects of flow alterations. The following sections are intended to elucidate the historic and present role of the IEP EMP in San Francisco Estuary water resource management and scientific investigations.

II. History of the IEP Environmental Monitoring Program

A. Origins

During the last 150 years, California's rapidly growing human population has altered the Delta almost beyond recognition. What was a system of occasionally salty marshes and flood plains interlaced by freely meandering channels only 150 years ago is now a network of leveed freshwater channels and dry, "reclaimed" islands. This altered system is heavily used for diverse purposes including water diversions, agriculture, recreation and urban and industrial development. Many of these uses require fresh water of "good quality."

To ascertain water quality, several government agencies and other groups initiated water quality studies and monitoring programs as early as the beginning of the 20th century. The earliest studies were concerned with seawater intrusions into the western and central Delta. Seawater intrusions are a natural feature of estuaries. In the Delta, they usually occurred in dry years or during the drier portions of the year (*e.g.*, late summer and fall). With the increasing extraction of Delta water for irrigation and urban and industrial purposes, these intrusions soon became a serious problem. Regular monitoring of salinity levels in the Delta began in 1920. The State initiated a more intense "Four-Day Chloride Sampling Program" in 1931 to provide frequent information about salinity intrusions. In 1940, the US Bureau of Reclamation (USBR) installed 15 continuous recorder stations designed to monitor electrical conductance throughout the Delta. Most of these stations were operated year-round and are still in use today as part of the State-mandated continuous water quality monitoring.

Water quality studies intensified with the planning and eventual operation of the Federal Central Valley Project (CVP, authorized in 1933) and the California State Water Project (SWP, approved in 1960). Both of these projects were designed to control salinity levels and flooding in the Delta and convey surplus, good-quality water from northern California to residents and agriculture in arid southern California and the San Joaquin Valley through an elaborate aqueduct system. Since most water was to be exported from the southwestern end of the Delta, it became even more important that the water in this region of the Delta remained sufficiently fresh and unpolluted.

With the authorization to build and operate the CVP, the USBR also accepted the responsibility for maintaining water quantity and quality and environmental aspects related to water supplies in the Delta. Thus most early environmental monitoring programs (1950s through 70s) associated with project operations were carried out under the auspices of the USBR. Four of these studies were combined in the “Delta-Suisun Bay Surveillance Program.” Two of these studies eventually became incorporated into the IEP Compliance Monitoring Program. These are the “Central Valley Operations Program” (present-day sites include a “C” in the station names) and the “Suisun Marsh Research and Testing Program” (present-day “S” sites). The two other studies focused on the effects of the planned San Luis Master Drain (“Delta-San Luis Drain Surveillance Program,” today’s “D” sites) and the Peripheral Canal (“Peripheral Canal Study Program,” today’s “P” site) on Delta water quality and hydrology. The San Luis Master Drain was meant to solve agricultural drainage problems in the San Joaquin Valley, while the Peripheral Canal would have routed North and East Delta water supplies intended for Southern California around rather than through the Delta. These two projects were never realized due to environmental concerns and lack of voter approval. However, the studies associated with these projects together with the other two studies have become the basis for today’s water quality monitoring efforts.

In addition to concerns about water quality for human uses, it soon became clear that human alterations of the Delta also affected fish and wildlife. Among the impacted species were important sport and commercial fishes such as salmon and striped bass and their food resources such as *Neomysis*. In 1961, the California Department of Fish and Game (DFG) initiated the "Delta Fish and Wildlife protection study" to investigate habitat requirements for the successful recruitment of fish and other organisms. Like the USBR studies, this study was eventually incorporated into mandated monitoring of the Delta. While monitoring of higher trophic levels (fishes, amphibians, and terrestrial organisms) has remained separate from water quality monitoring, lower trophic level investigations (phytoplankton, *Neomysis*/zooplankton, benthic organisms) were integrated with physical and chemical water quality monitoring into a coordinated Environmental Monitoring Program starting in 1971.

Additional data on water chemistry, suspended sediments, and temperature were supplied to DWR by the United States Geological Survey (USGS). The USGS data were collected and published as part of the countrywide USGS Surface Water Quality Program starting in 1941. The USGS also measured the amount and nature of suspended sediments at three Delta stations. However, most of the early USGS studies focused on San Francisco Bay and San Pablo Bay rather than on the Delta; this is still the case today.

Agencies involved in water quality monitoring started to systematically coordinate their efforts in 1970. At this time, USBR, DWR, DFG, and the US Bureau of Sport Fisheries and Wildlife signed a Memorandum of Agreement to coordinate environmental studies in the Delta and Suisun Bay including water quality monitoring and special studies. The agreement was a result of concerns voiced during hearings for Water Right Decision D-1379 about potential negative effects of the CVP and SWP on fish and wildlife. The agencies formed the “Interagency Ecological Studies Program” (IESP) to study and address these problems. During its first decade of existence, IESP studies and monitoring efforts focussed on how to best develop the water projects while protecting fish and wildlife, resulting in the recommendation to build a Peripheral Canal. After the electoral defeat of this project, IESP turned its attention to the effects of operational changes and barriers. With increasing environmental degradation in the Delta and greater public attention to environmental problems, IESP has grown considerably both in scope and membership in the last two decades. In 1994, the IESP name changed to Interagency Ecological Program (IEP). Today, the IEP consists of nine agencies with a stated mission to “provide information on the factors that affect ecological resources in the Sacramento - San Joaquin Estuary that allows for more efficient management of the estuary.” Interagency projects are grouped into three “work components:” Estuarine Management, Special Studies, and Monitoring. The EMP is the main project of the IEP Monitoring work component.

The California Department of Water Resources (DWR) came to play a leading role in Bay-Delta water quality monitoring activities only after the formation of the IESP in 1970 and passage of the first water right decision jointly addressing SWP and CVP operations in 1971. Created in 1956 from several predecessor offices and agencies, DWR is charged with developing and managing the state’s water resources. Around the time of its creation, it directed several environmental data collection programs throughout the state designed to provide information necessary for carrying out its mission. Data collected in the Delta included measurements of river stage and other physical parameters, as well as measurement of surface, waste, and drainage water chemical and biological parameters. Initially, DWR’s core study focused on planning for the implementation of Delta water facilities. Environmental impact assessment and water quality control were not required of DWR before 1971. DWR and DFG came to share the responsibility for carrying out most elements of the compliance monitoring mandated by the State Water Resources Control Board (SWRCB) starting in 1971.

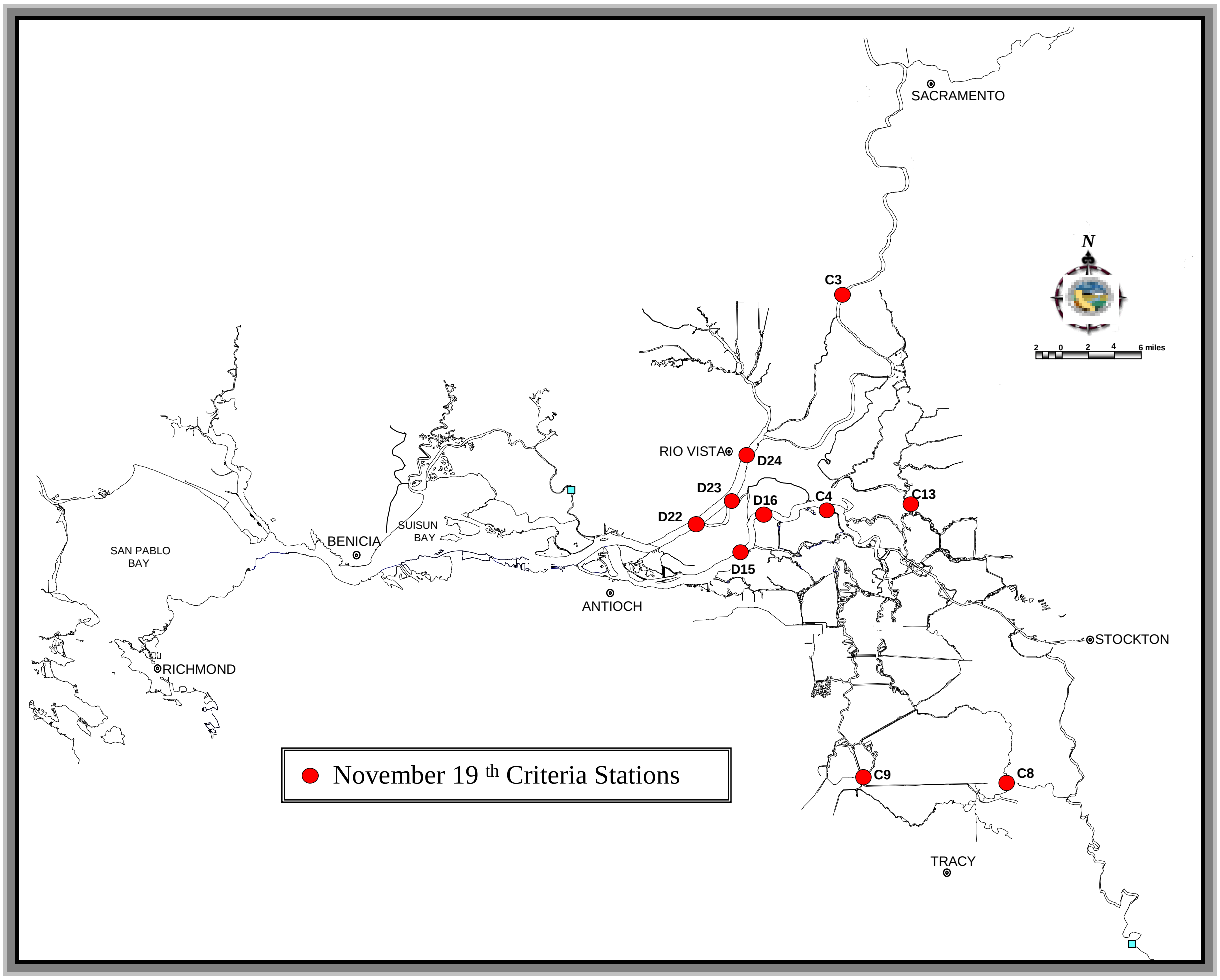
B. Legal aspects

Environmental monitoring and research in the Delta is mandated by and intricately linked with environmental law. The purpose and legal obligation of environmental monitoring and research is to provide information for effective resource management and compliance with water quality standards set by state law. The current IEP EMP design can only be understood and evaluated with this legal background in mind. The following sections give a brief historical overview of the pertinent legislative developments. More detailed information on the legal background of the IEP EMP as well as a timeline of major legal and program developments can be found in Appendix 1.

Mandatory water quality standards (also referred to as requirements, objectives, or criteria) have provided the basis for regulatory action regarding water quality in the Delta. According to the California Water Code, a water quality objective is defined as "the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area." (Wat. Code §13050(h)). Further, "Quality of the water" is defined as "chemical, physical, biological, bacteriological, radiological, and other properties and characteristics of water which affect its use." (Wat. Code §13050(g)).

The first California water quality standards were defined and published in 1952 by the newly formed State Water Pollution Control Board (SWPCB; a precursor of the State Water Quality Control Board (SWQCB)). However, for more than a decade thereafter, California did not adopt statewide or regional water quality standards. A first step toward regional legislative regulation for the Bay-Delta was an agreement by DWR, USBR, the Sacramento and Delta Water Association, and the San Joaquin Water Rights Committee on interim water quality criteria (TDS and Chlorides) and their assessment in November 1965. This agreement came to be known as the “November 19th Agreement” and represents one of the earliest interagency agreements on water quality standards and monitoring in California. The agreement included 10 Delta monitoring stations known as “November 19th criteria stations” (Fig. 2).

Fig. 2: TDS and Chloride monitoring stations identified in the November 19th, 1965 Interagency Agreement and included in D-1275 of 1967.



In 1967, the California State Water Resources Control Board (SWRCB) was created through a fusion of the State Water Quality Control Board and the State Water Rights Board for the dual purpose of determining water rights and regulating water quality. Subsequently, two types of documents issued by the SWRCB provided regional water quality regulation: Water Quality Control Plans set water quality standards and Water Right Decisions permitting the appropriation of water implemented these standards as permit requirements. The "November 19th Agreement" with its salinity and TDS standards and monitoring program was the first approximation to a regional Water Quality Control Plan for the Delta. The "November 19th Criteria Stations" were included in State Water Right Decision D-1275 of 1967 which approved water rights for the SWP. As a result, this decision became the first California regulatory document to mandate compliance with water quality standards. However, the scope of these standards was limited to salinity and did not encompass standards for the protection of fish and wildlife and pollution control.

The first Regional Water Quality Control Plan (Basin Plan) for the Sacramento-San Joaquin Delta ("Sacramento-San Joaquin Delta Water Quality Control Plan") was completed in 1975. It contained a set of water quality standards resembling requirements in SWRCB Water Right Decision D-1379 of 1971. This 1971 decision concerned water rights for both the SWP and CVP. As part of the permits for these projects, D-1379 specified mandatory standards for salinity, TDS, and flow and a comprehensive compliance water quality monitoring program designed to provide the necessary information for meeting these standards. Additional studies were supposed to be conducted to define standards for temperature, velocity, algal growth, dissolved oxygen, scour, and turbidity in parts of the San Joaquin and Sacramento Rivers susceptible to flow alterations.

D-1379 and the 1975 Basin Plan were superceded in 1978 by D-1485 and the "Water Quality Control Plan for the Sacramento-San Joaquin Delta and the Suisun Marsh" (the "1978 Plan" or "Delta Plan"). Both documents augmented and revised previous water quality standards related to salinity control and fish and wildlife protection via flow regulation. D-1485 standards were based on the potential degree of protection that municipal, industrial, agricultural, and fish and wildlife uses would have experienced in the absence of the SWP and CVP. The SWP and CVP were ordered to make operational decisions aimed at maintaining Delta water quality and specified flows. D-1485 also added fisheries monitoring in San Francisco Bay and Suisun Marsh monitoring to the compliance monitoring program and required additional "special studies" to meet specific needs. D-1485 remained in effect for almost thirty years. EMP sampling station locations and parameters from 1971 through 2000 are described in detail in section II D of this document.

In the late 1980s, several phases of hearings began for a new water quality control plan and a new water right decision for the entire Bay-Delta complex including San Francisco Bay. No conclusive decisions occurred until 1994 when State and federal officials announced their agreement on comprehensive Bay-Delta standards ("Bay-Delta Accord") which paved the way for the adoption of a widely accepted new Water Quality Control Plan for the Bay-Delta in May 1995 ("Bay-Delta Plan"). This plan sets standards for salinity (chloride and electrical conductivity (EC)), dissolved oxygen (DO), flow, and water project operations. As part of the hearings process, DWR and USBR with the help of IEP conducted an extensive review of the D-1485 Environmental Monitoring Program. The resulting revised monitoring plan was approved by the SWRCB in December 1995 and implemented starting in January 1996. It became part of the Bay-Delta plan and the subsequent water right order WR 95-6 issued by SWRCB in June 1995. This order temporarily amended terms and conditions of D-1485 to meet the new standards set forth by the Bay-Delta Plan. WR 95-6 was itself amended in

SWRCB Order 98-09 of 1998. Finally, a new water right decision, D-1641, was adopted in December 1999 and revised in March 2000. It contains the standards and monitoring plan with stations and parameters specified in the Bay-Delta Plan.

C. Objectives

The main task of the IEP EMP since its inception in 1970 has been to provide information for water resource management in compliance with flow-related water quality standards set forth in the series of Water Right Decisions described above. These decisions permit the USBR and DWR to appropriate water for operation of the CVP and the SWP. In return, the two agencies are required to monitor the effects of diversions and flow manipulations resulting from project operations and ensure the compliance with existing water quality standards. The IEP EMP shares the responsibility for water right permit compliance monitoring with a continuous salinity recorder program carried out by DWR's Central District. In addition to providing flow management information, compliance monitoring and accompanying special studies have also tackled various other issues such as detection of introduced species and providing data for model calibration and verification. The original IEP EMP objectives and new objectives after two major program revisions in 1978 and 1994/95 are summarized in Table 1. Most of these objectives have been extracted from Water Right Decisions and Water Quality Control Plans referenced in the table and merged with objectives found in several DWR and IEP program plans and reports.

Table 1: IEP EMP objectives

A) 1970/71 (Creation of IEP and enactment of D-1379)

1. Provide information necessary to achieve compliance with "State Delta Standards" for salinity and TDS
2. Provide biological and hydrological baseline information
3. Provide information about how to best develop the State's water resources while protecting all beneficial uses of water resources
4. Provide data for planning and operation of CVP, SWP, Peripheral Canal, and San Luis Master Drain
5. Provide information for periodic adaptation of standards and monitoring to changes in conditions
6. Develop correlations between fish and lower trophic level productivity and amend standards to reflect these results
7. Conduct additional studies to define standards for various other variables potentially affected by flow alterations and to address adverse effects of algal blooms (eutrophication)
8. Continuously evaluate and revise the monitoring program

B) 1978 (Delta Plan and D-1485)

1. Provide information necessary to achieve compliance with revised salinity standards as well as with flow standards
2. Identify and report meaningful changes in significant water quality parameters and trends in ecological changes potentially related to operations of the CVP and SWP
3. Develop and improve water quality and biological predictive tools
4. Propose and provide data for special studies to develop a better understanding of the hydrodynamics, water quality, productivity and significant ecological interactions of the Delta and Suisun Marsh so that more accurate predictions of environmental impacts of the CVP and SWP can be made
5. Provide information for periodic adaptation of standards and monitoring to changes in conditions
6. Continuously evaluate and revise the monitoring program

C) 1995 to present (Bay-Delta Plan and D-1641)

1. Provide information necessary to achieve compliance with revised salinity and flow standards as well as with DO standards
2. Identify and report meaningful changes in significant water quality parameters and trends in phytoplankton, zooplankton, and benthos abundance, distribution, and composition potentially related to operations of the CVP and SWP
3. Develop and improve predictive tools (models) to evaluate project and non-project effects
4. Evaluate the response of organisms and aquatic habitat to the water quality standards
5. Increase the current understanding of large-scale characteristics and functions of the Delta ecosystem to better predict system-wide responses to management options
6. Provide information for the management and possible eradication of exotic species
7. Coordinate IEP and Non-IEP Bay-Delta monitoring programs to minimize duplication and facilitate the exchange of data
8. Maintain a streamlined baseline surveillance effort with less, more strategically placed discrete (boat) sampling and more continuous, multi-parameter sampling as well as more special studies accompanying the monitoring program
9. Maintain a long-term baseline record and provide a consistent, long term record of trends
10. Provide accurate and validated water quality information on a timely basis in a format appropriate for a variety of users

11. Respond to the findings of ongoing monitoring, changing conditions in the Bay-Delta, and the needs of Management by proposing special studies to provide needed information in a timely manner
12. Establish and adhere to a comprehensive quality assurance/quality control program
13. Regularly evaluate and revise the monitoring program

Although the primary objectives of the IEP EMP have remained the same since its inception, these successive lists of objectives also reflect some of the changes in environmental conditions and resource management demands as well as increased knowledge about the system. Over time, the program has also been able to accommodate some of the demands resulting from the changing political, sociological, and environmental climate in California. In general, resource management concepts evolved from strategies focused on maximizing human resource use to strategies where ecosystem integrity and the importance of habitats for ecosystem processes have an important role in the overall management strategy. The resulting balance in strategies are at the core of the CALFED process. How the EMP can best fit into this new environment is still unclear and should be addressed in the 2001 review. A discussion of links between the IEP EMP, current ecological and applied research questions, and CALFED can be found in CALFED CMARP Appendix VII A 5: "Estuarine System Productivity: Lower Trophic Levels" (1999; http://calfed.water.ca.gov/programs/cmarp/a7a5.html). This document discusses monitoring and research needs for two stated goals of the CALFED Strategic Plan for Ecosystem Restoration:

1. Rehabilitate the capacity of the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities
2. Provide good water quality for all beneficial uses.

As the CMARP document points out, these goals are closely related. While the second goal coincides with the purpose of the mandatory water quality standards and thus with the impetus for the EMP, the first goal reflects the new ecological awareness infusing environmental management strategies. The increased appreciation of ecological processes and the new conceptual management framework provided by CALFED may thus serve as guideposts for the critical evaluation of the current IEP EMP objectives.

D. Sampling Stations, Parameters, and Schedules

Most stations and parameters of the Interagency Environmental Monitoring Program were established based on recommendations by a 1970 Stanford Research Institute (SRI) study commissioned by SWRCB or derived from the preceding “Delta-Suisun Bay Surveillance Program” and the “Delta Fish and Wildlife protection study.” Original stations included both continuous recorder (shore stations) and discrete (boat or van) sampling sites. The original number of discrete stations was expanded in 1978 to accommodate compliance monitoring for new water quality standards. The number of stations was reduced due to streamlining efforts in the face of budgetary constraints and to free up funds for more special studies in 1995. With the exception of one multi-parameter station (Sacramento River at Hood) and two entrapment zone sites (variable location depending on bottom EC values (2000 and 6000 μS)), no completely new stations have been added throughout the program. Also, most parameters measured today are among the original parameters measured in 1970. The most substantial changes occurred relatively recently with the addition of a continuous, multi-parameter recording network starting in 1983, on-board recording of horizontal and vertical profiles of several constituents, and the discontinuation of 15 discrete sampling sites starting in 1996. Zooplankton sampling was part of the original 1970 monitoring program, then became a separate program until being integrated again in 1995. Heavy metal and pesticides monitoring was conducted through 1995 and then discontinued. The following section describes the evolution and justification of sampling stations, parameters, and schedules. The station information is summarized in Table 2.

Table 2: IEP Environmental Monitoring Program sampling stations since 1971. Discrete, phytoplankton, zooplankton and boat sampling is conducted by boat or lab van. Multiparameter monitoring is accomplished via continuously recording shore stations. See also Figure 3 and 4 for station locations. (Note: Continuously operated compliance monitoring shore stations listed in water right decisions but not part of the IEP EMP are not shown here.)

Station ID (IEP)	Description	Latitude	Longitude	November 19th, 1965 Criteria Stations	Recom-mended by SRI in 1970	D-1379 (1971)	D-1485 (1978)	Bay-Delta Plan[1] (1995)	Discrete[2]	Multipara-meter[3]	Phyto-plankton	Zooplank-Ton[4]	Benthos	Heavy Metals & Pesticides[5]
C3	Sacramento River @ Greens Landing	38§ 20' 45"	121§ 32' 42"	♦	•	x	x	x	x		x		(x)	(x)
C7	San Joaquin River @ Mossdale Bridge	37§ 47' 11"	121§ 18' 22"		•	x	x	x	(x)	1984	(x)		(x)	(x)
C9	West Canal at mouth of CC Forebay Intake	37§ 49' 50"	121§ 33' 09"	♦	•	x	x	x	(x)		(x)		xx	
C10	San Joaquin River near Vernalis	37§ 40' 34"	121§ 15' 51"		•	x	x	x	x		x			
D4	Sacramento River above Point Sacramento	38§ 03' 45"	121§ 49' 10"				x	x	x		x	xxx	x	(x)
D6	Suisun Bay @ Bulls Head nr. Martinez	38§ 02' 40"	122§ 07' 00"		•		x	x	x	1983	xx	xxx	x	(x)
D7	Grizzly Bay @ Dolphin nr. Suisun Slough	38§ 07' 02"	122§ 02' 19"		•	x	x	x	x		x	xxx	x	(x)
D8	Suisun Bay off Middle Point nr. Nichols	38§ 03' 36"	121§ 59' 20"				x	x	x		x	xxx		
D9	Honker Bay near Wheeler Point	38§ 04' 26"	121§ 56' 12"				x		(x)		(x)		(x)	(x)
D10	Sacramento River @ Chipps Island	38§ 02' 47"	121§ 55' 02"		•	x	x	x	(x)	1984		xxx		
D11	Sherman Lake near Antioch	38§ 02' 34"	121§ 47' 34"				x		(x)				(x)	(x)
D12	San Joaquin River @ Antioch Ship Channel	38§ 01' 15"	121§ 48' 28"		•	x	x	x	(x)	1983	(x)	xxx		
D14A	Big Break near Oakley	38§ 01' 05"	121§ 42' 38"		•	x	x		(x)				(x)	(x)
D15	San Joaquin River @ Jersey Point	38§ 03' 09"	121§ 41' 17"	♦	•	x	x	x	(x)		(x)			
D16	San Joaquin River @ Twitchell Island	38§ 05' 50"	121§ 40' 05"	♦	•	x	x	x	(x)			xxx	xx	
D19	Frank's Tract near Russo's Landing	38§ 02' 38"	121§ 36' 49"				x		(x)				(x)	(x)
D22	Sacramento River @ Emmaton	38§ 05' 04"	121§ 44' 17"	♦	•	x	x	x	(x)			xxx		
D24	Sacramento River below Rio Vista Bridge	38§ 09' 27"	121§ 41' 01"	♦	•	x	x	x	(x)	1983	(x)		xx	
D26	San Joaquin River @ Potato Point	38§ 04' 40"	121§ 34' 00"				x	x	x		x	xxx		
D28A	Old River opposite Rancho Del Rio	37§ 58' 14"	121§ 34' 19"		•	x	x	x	x		xx	xxx	x	(x)
D29	San Joaquin River @ Prisoners Point	38§ 03' 32"	121§ 33' 23"			x	x	x		x				
D41	San Pablo Bay near Pinole Point	38§ 01' 50"	122§ 22' 15"					xx	xx		xx		xx	
*D41A**	San Pablo Bay nr. Mouth of Petaluma R.	38§ 03' 75"	122§ 24' 40"					xx					xx	
D42	San Pablo Bay nr. Rodeo						x		(x)		(x)			
P8	San Joaquin River @ Buckly Cove	37§ 58' 42"	121§ 22' 55"		•	x	x	x	x	1983	x	xxx	x	(x)
P10	Middle R.@ Borden Highway					x	x		(x)					
*P10A**	Middle R.@ Union Pt.	37§ 53' 28"	121§ 29' 14"						(x)					
P12	Tracy Road Br.	37§ 48' 17"	121§ 26' 55"			x	x	x	(x)					

Table 2 continued.

Station ID (IEP)	Description	Latitude	Longitude	November 19th, 1965 Criteria Stations	Recom-mended by SRI in 1970	D-1379 (1971)	D-1485 (1978)	Bay-Delta Plan[1] (1995)	Discrete[2]	Multipara-meter[3]	Phyto-plankton	Zooplank-ton[4]	Benthos	Heavy Metals & Pesticides[5]
MD6	Sycamore Slough near Mouth						x		(x)		(x)		(x)	(x)
MD7	SF Mokelumne below Sycamore Slough						x		(x)		(x)		(x)	(x)
MD10	Disappointment Slough near Bishop Cut	38§ 02' 38"	121§ 25' 04"				x	x	x		x	xxx		(x)
S42	Suisun Slough 300' south of Volanti Slough	38§ 10' 50"	122§ 02' 45"		•	x	x	x	(x)			xxx		
NZ032	Montezuma Slough, 2nd bend from mouth	38§ 10' 17"	122§ 01' 03"					x				xxx		
70 (for C3)	Sacramento River @ Hood	38§ 22' 02"	121§ 31' 13"							1998				
*NZ325**	San Pablo Bay near Rock Wall and Light 15	38§ 03' 29"	122§ 17' 27"									xxx		
*NZ02**	Carquinez Strait near Glen Cove	38§ 03' 51"	122§ 12' 53"									xxx		
*NZ04**	Ozol near Martinez and Light 25	38§ 02' 09"	122§ 09' 38"									xxx		
*EZ2**	Entrapment Zone - Location determined when bottom EC values occur at approximately 2000 us	Variable	Variable									xxx		
*EZ6**	Entrapment Zone - Location determined when bottom EC values occur at approximately 6000 us	Variable	Variable									xxx		

1 Also in D-1641, 2000

2 Physical, chemical and biological parameters, see Table 4 and Appendix 2 for parameters sampled

3 Initiated in 1983 (years indicated), mandated starting in 1995. D-29: EC and temperature only

4 Integrated in 1995 (was separate program with many more stations before)

5 Discontinued after 1995

* Not SWRCB mandated, but part of monitoring program since 1995

♦ November 19th, 1965, Criteria Station

• Recommended sampling site

x Mandated sampling site

xx Added or reinstated in 1995

xxx Integrated in 1995

(x) Discontinued in 1995

D-1379 Stations

Water Right Decision D-1379 of 1971 listed 32 monitoring stations including nine of the ten “November 19th Criteria Stations.” Stations were selected based on recommendations by the 1970 SRI study. This study gave approximate station locations intended to capture the system characteristics shown in Table 3.

Table 3: System characteristics represented by sampling stations proposed by SRI (1970). In parentheses: Number and IEP ID of proposed stations described as fitting these characteristics (“SRI” stations: stations proposed by SRI but not implemented)

1. Geographic areas (all Stations)
2. Geomorphologic/hydrologic variation (20 Stations)
    - a) Deeper channels (7 Stations: C14, D6, D12, D15, D22, D23, P8)
    - b) Strongly tidal channel (5 Stations: C2, C14, D6, D7, D10)
    - c) Shallower channel (2 Stations: C7, D24)
    - d) Embayments (2 Stations: D7, D14A)
    - e) Sloughs (2 Stations, P4, D14A)
    - f) Moderately tidal channel (1 Station: P8)
    - g) Interior tidal marsh (1 Station: S42)
3. Salinity control (13 Stations)
    - a) "Nov. 19th 1965 criteria stations" (7 Stations: C8, C9, D15, D16, D22, D23, SRI15)
    - b) Salinity intrusion (6 Stations: C14, D6, D7, D10, D12, D24)
4. Flows/project operations (13 Stations)
    - a) Inflows and outflows (9 Stations: C3, C4, C9, C10, D6, D10, D24, D28A, SRI12)
    - b) Peripheral Canal (3 Stations: C3, D28A, P4)
    - c) Interdelta flows (1 Station: SRI15)
5. Pollution (11 Stations):
    - a) Industrial waste water (6 Stations: C2, C14, D6, D10, D12, SRI 22)
    - b) San Luis Drain (3 Stations: C2, D12, D15)
    - c) Agriculture (1 Station: SRI20)
    - d) Proposed thermal power plant (1 Station: C2)

The SRI criteria for station selection mirrored the then prevailing concerns about the effects of water uses and resource management. The attempt to cover the Delta’s geomorphologic and hydrologic variation through the recommended sampling stations may be seen as a precursor to later interest in habitat variations. However, the SRI criteria for sampling stations did not mention habitats or explicitly justify the station recommendations from a biological/ecological perspective. In the D-1379 monitoring plan the stations recommended by SRI were matched to sites sampled in previous studies, thus retaining the “C”, “D”, “S”, and “P” designations of the previously established site names.

D-1379 Parameters

Monitoring parameters included in D-1379 were also based on the SRI study of 1970. The selection of monitoring parameters by SRI started with the classification of resource uses potentially affected by water project operations and other human activities such as waste water discharges. The resource uses considered in the SRI Study were:

1. Municipal water supply
2. Industrial water supply
3. Agricultural water supply
4. Fish and wildlife propagation and sustenance
5. Recreation
6. Enjoyment of esthetic values
7. Navigation
8. Commercial Fishing and Shellfishing
9. Historical value (background data, related to future use or used in specifying water quality standards)

76 measurable water quality properties directly related to these resource uses were identified. For example, the measurable water quality parameter “chlorophyll” was recognized as primarily associated with resource uses 1, 2, 5, and 6. Parameters were further classified according to their effects on uses or organisms. “Chlorophyll” was thus recognized as directly and indirectly related to important food chain constituents and turbidity, and as having effects dependent on other properties of the water. Based on these evaluations, the 76 parameters were then separated into four priority categories with 26 variables receiving highest priority (Table 4).

Table 4: Priority parameters proposed by SRI (1970)

BOD	Water Temperature
Chlorides	Air Temperature
Chlorophyll	Turbidity
Electrical conductance	Water Flow
Light Transmittance	Benthos, quantitative
Nitrates	Benthos, qualitative
Organic Nitrogen	Fecal Coliforms
Dissolved Oxygen	Fish, qualitative
pH	Photosynthesis rate
Total Phosphates	Phytoplankton, quantitative
Sediment Profile and Composition	Phytoplankton, qualitative
Total Dissolved Solids (TDS)	Zooplankton, quantitative
Total Suspended Solids (TSS)	Zooplankton, qualitative

Monitoring of various heavy metals and pesticides as well as macrophytes was also highly recommended (priority 2).

D-1379 included all SRI priority 1 parameters listed above as well as heavy metals and pesticides in its list of mandatory monitoring parameters. It expanded fish monitoring to include quantitative indices and YOY striped bass counts. D-1379 also adopted the monitoring schedule recommended by SRI. Parameters were to be measured on schedules ranging from continuous to weekly, monthly, seasonally, and annually, with most variables requiring continuous or weekly measurements.

D-1485 stations and parameters

D-1485 of 1978 expanded the water quality monitoring stations to 44 sites including 24 of the 32 D-1379 stations. 29 of the 44 sites became part of the IEP EMP (Table 2 and Fig. 3), while the remaining stations (all continuous EC recorder sites) were operated by a separate DWR unit. D-1485 split the monitoring parameters into six broad categories with different sampling frequencies:

Table 5: D-1485 Parameter categories

Parameter category	Sampling Frequency
Electrical conductivity	Continuous measurements
Base parameters[1]	Monthly or semi-monthly measurements
Phytoplankton	Monthly or semi-monthly measurements
Phosphorus, TDS, and Cl-	Monthly measurements
Heavy metals and pesticides	Semi-annual measurements
Benthos	Semi-annual measurements

[1] Base parameters: Air and water temperature, EC, pH, DO, turbidity, water depth to 1% light level, Secchi depth, suspended solids, nitrate, nitrite, ammonia, organic nitrogen, silica, chlorophyll *a*

The fish and zooplankton monitoring components were transformed into larger, independent monitoring programs carried out by DFG and largely funded by DWR and USBR. In addition to the previously measured parameters, D-1485 also included Secchi disc depth, volatile as well as non-volatile suspended solids, nitrite, and silica measurements. Most of the water quality monitoring activities specified in D-1485 were carried out by DWR staff with additional funding from USBR. Starting in 1983, several continuous multi-parameter recorders housed in covered shore stations were added to the EMP.

Fig. 3: IEP EMP stations 1978-1995 (D-1485).

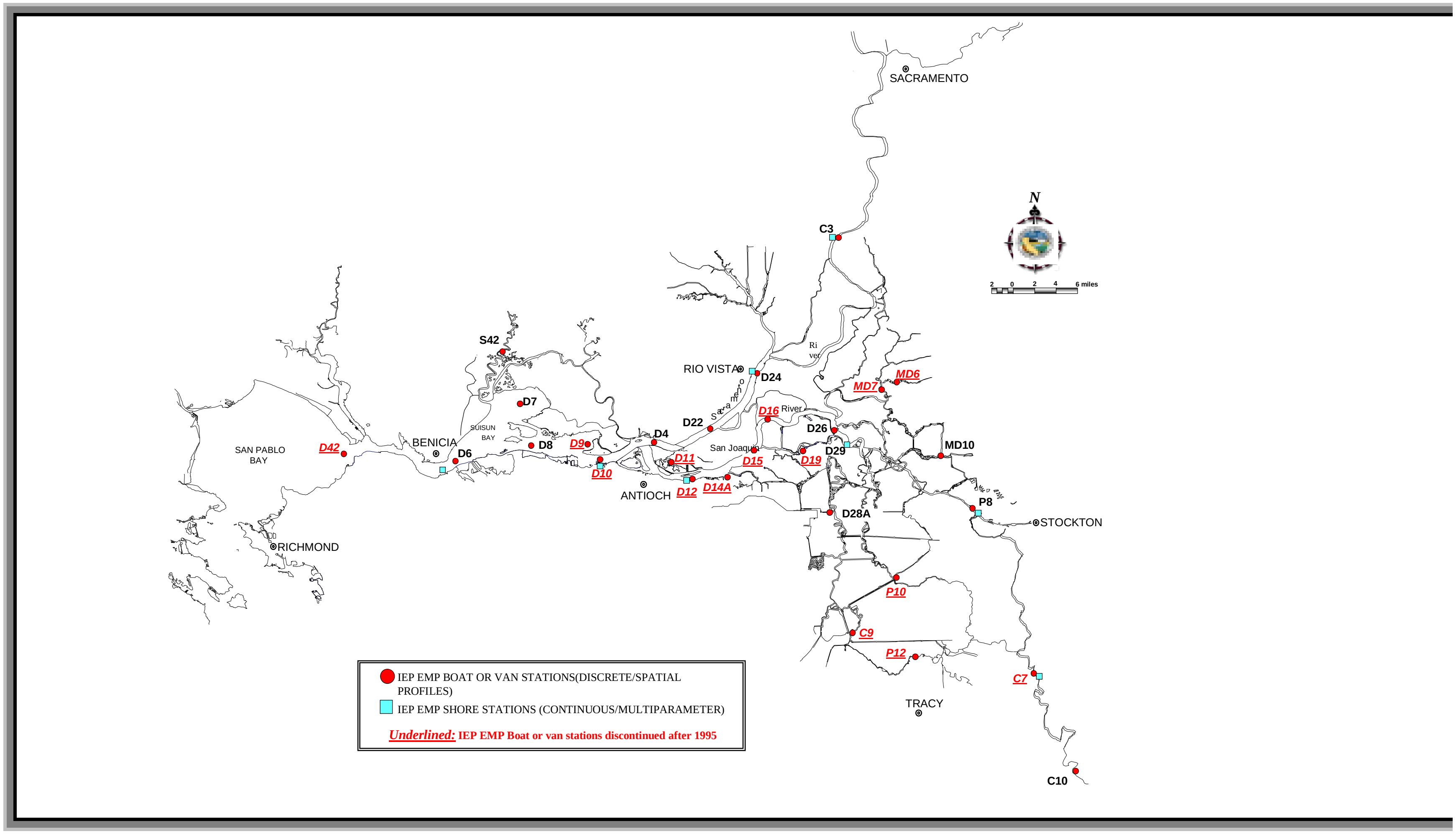


Fig. 4: IEP EMP stations after1995 (D-1641).

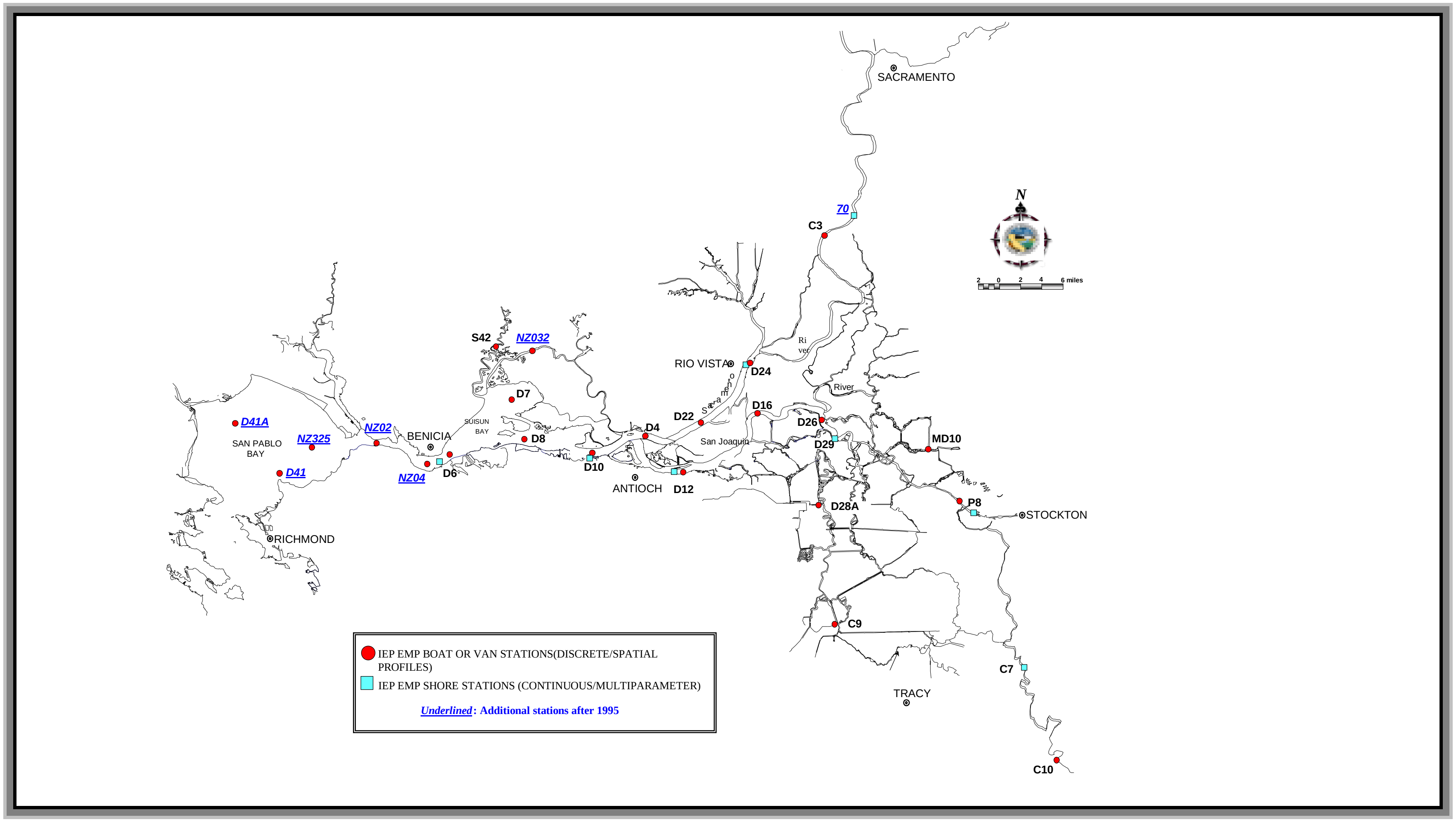
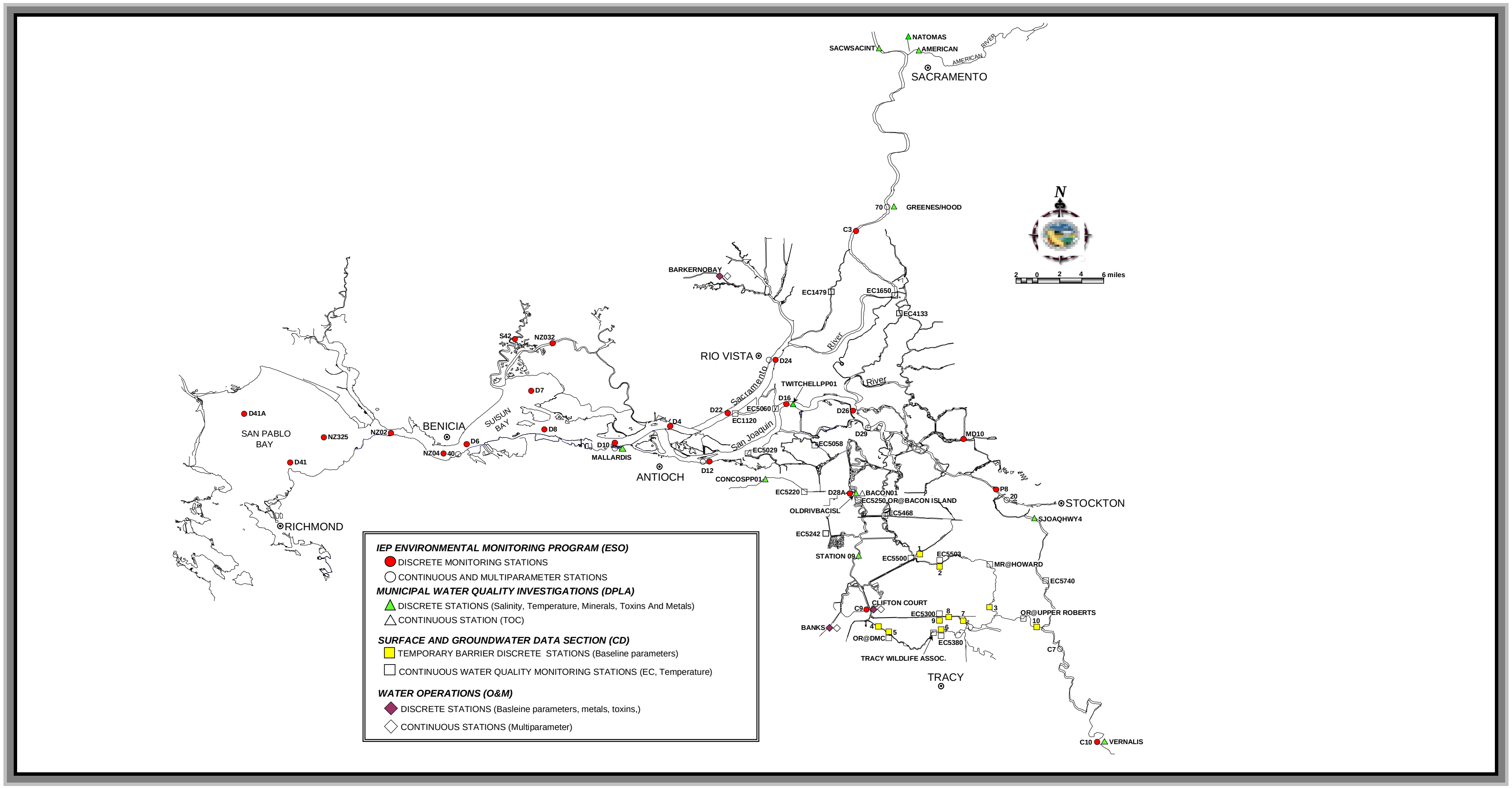


Fig. 5: Current DWR Delta monitoring stations (Adapted from: DWR Delta Water Quality Program Review, September 2000)



WR 95-1/D-1641 stations and parameters

The Bay-Delta Plan of 1995 (WR 95-1) and D-1641 of 2000 incorporate revisions to the monitoring program recommended in an extensive review process (see section III). Of the 42 stations of the revised program, 30 were included in D-1485, while the remainder are new or reinstated older stations. 21 mandated compliance monitoring stations (all continuous EC recorder sites) are not part of the IEP EMP and not described here. In an effort to streamline the discrete sampling program, discrete sampling sites were grouped into regions based on individual and combined hierarchical cluster analysis for 14 physical and chemical variables and chlorophyll *a* concentrations (Appendix 2, Table 2c). These regions were similar to those determined for an independent analysis of phytoplankton community composition (Lehman and Smith 1991). Results of this analysis reduced the number of discrete sampling sites from 28 to 11 sampling sites. Several phytoplankton and benthos monitoring sites were also discontinued while at the same time several new sites were added. *Neomysis*/zooplankton monitoring was reintegrated with the IEP EMP in 1995, while pesticide and heavy metal monitoring were completely discontinued (Table 2, Fig. 4).

In addition to the traditional EC continuous recorder sites, the Bay-Delta Plan also mandates multi-parameter monitoring sites for the continuous, telemetered assessment of water temperature, pH, DO, EC, turbidity, and chlorophyll. Also, besides the discrete grab samples at 1 m depth, the Bay-Delta Plan contains on-board recording of vertical and horizontal water temperature, DO, EC, turbidity, and chlorophyll a profiles. Boat, van, and multi-parameter monitoring activities are carried out by DWR-ESO, while the continuous compliance monitoring recorder stations are operated by USBR and others. Only the DWR-ESO/DFG supported monitoring is part of the IEP EMP review process. Detailed information about the current IEP EMP can be found in Appendix 2.

Sites, parameters, and system properties not considered by the IEP EMP

There are several other Delta monitoring programs conducted by federal and state agencies complementing the IEP EMP. They are summarized in a 1997 DWR publication entitled “Compendium of Water Quality Investigations in the Sacramento River Watershed, the Sacramento-San Joaquin Delta, and San Francisco Bay.” In addition to parameters monitored by the EMP, these programs also measure organic carbon, several toxins, heavy metals, and pathogens. Fig. 5 shows stations and parameter categories monitored by four DWR programs. In spite of these additional monitoring efforts, several types of sites and variables have not been targeted as part of a formal long-term monitoring program such as the IEP EMP. These include:

1. Shallow water habitats (e.g. floodplains, shallow tidal marsh sites, shallow lakes);
2. Restored sites;
3. Aquatic macrophytes;
4. Microbial organisms and activities (except for some pathogens).

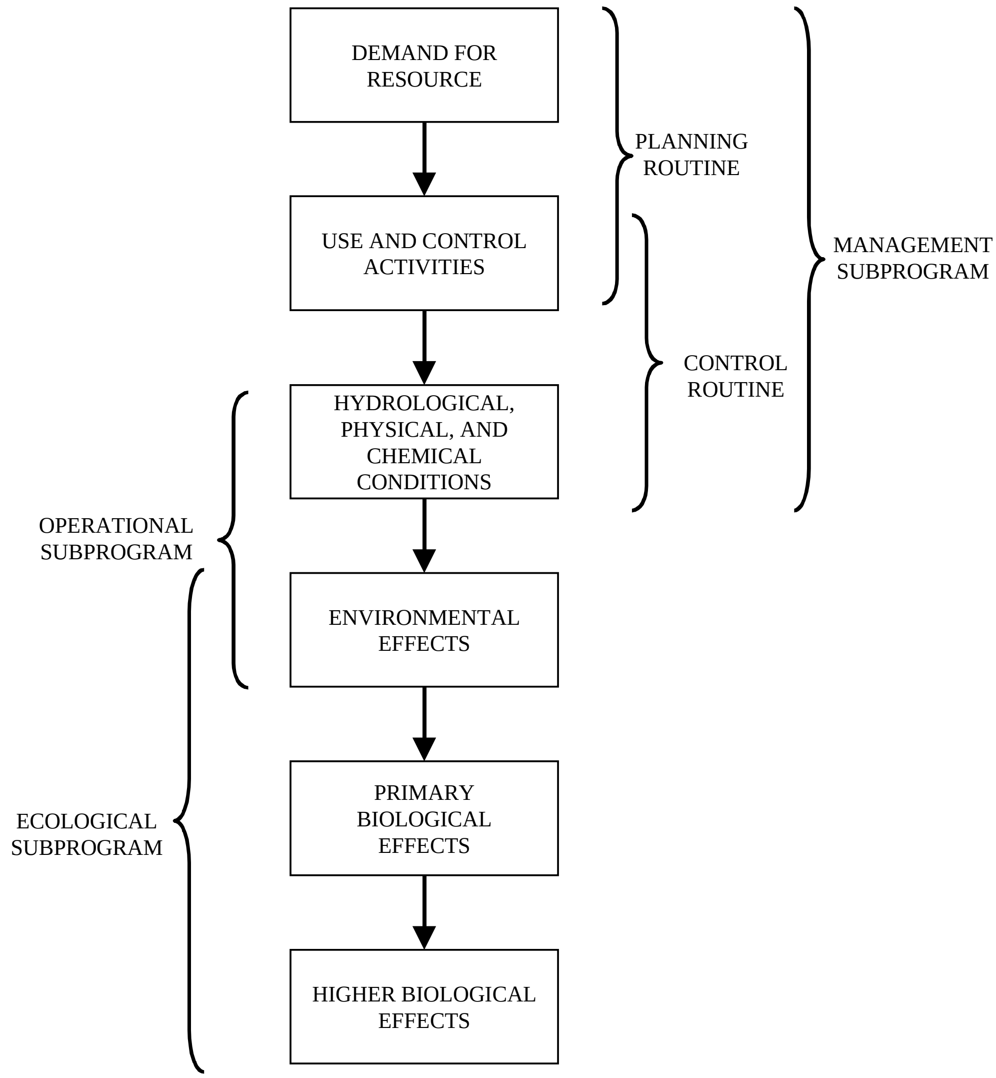
The absence of these sites and variables from the EMP can be explained with its historic focus on the effects of resource management on water quality for human uses instead of ecosystem functions. Due to the ecological importance of these system components in biogeochemical cycling, trophic interactions, and for some life stages of well-studied organisms such as fish, their absence may be a short-coming of the program.

Some important system properties have also not been addressed in detail by the IEP EMP. These include the effects of tidal variability on water quality monitoring results within and between sites and small-scale spatial variability in water quality, *e.g.* across channel variability.

E. Conceptual Models

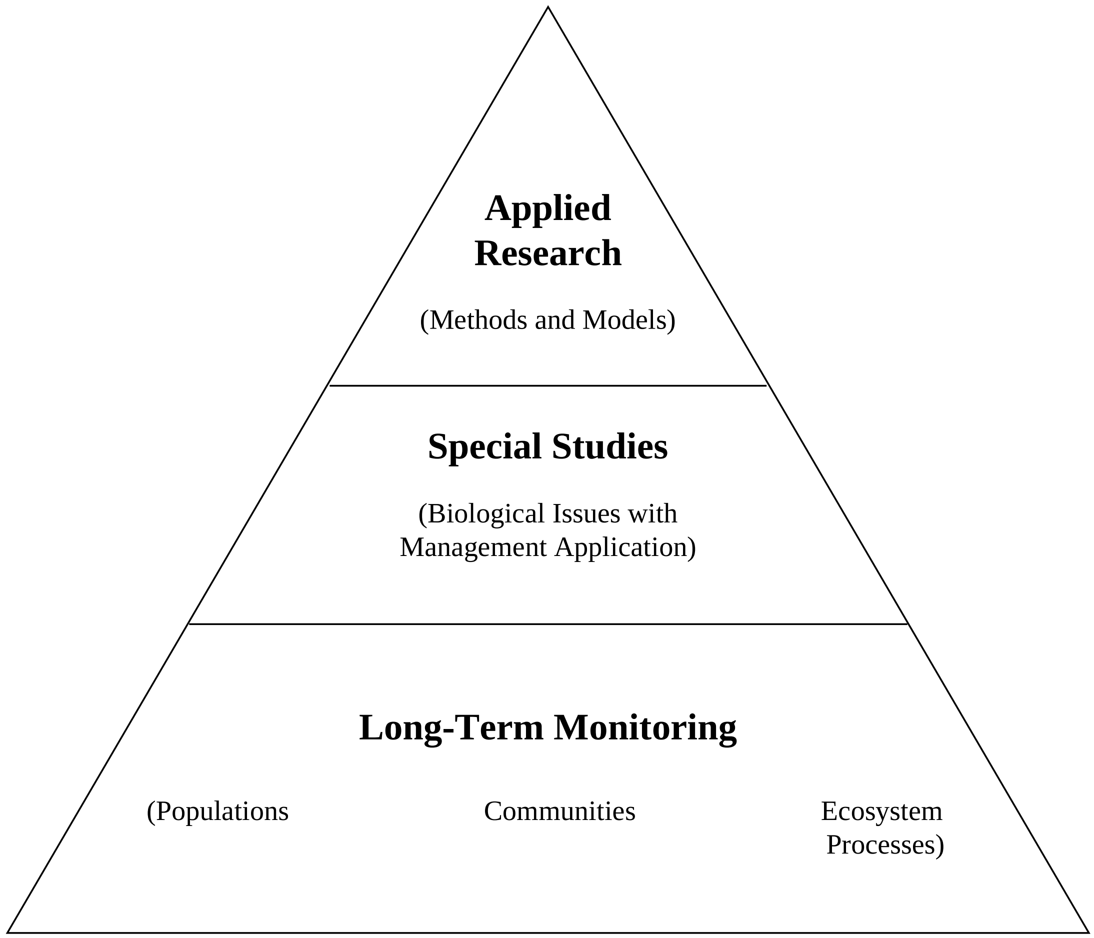
In spite of their potential usefulness in clarifying the relationships among the various program components as well as the program's relationship with other studies and management tasks, there have been few conceptual models for the IEP EMP. The first conceptual model was provided in 1970 by the SWRCB/SRI program plan (Fig. 6). This model was used to place the environmental study and monitoring program in the context of environmental resource use activities.

Fig. 6: SWRCB/SRI Study (1970): Conceptual Model for the "Sacramento-San Joaquin Delta and Suisun Bay Environmental Predictive Program".



A second conceptual model was included in the 1995 review of the IEP program by the CUWA/Ag Technical Committee. This review presents a conceptual model of IEP in which the long-term IEP monitoring programs including the EMP serve as the foundation of the IEP program. This foundation supports special studies and applied research. The CUWA/Ag review also emphasizes the necessity of ecology-based monitoring from population dynamics to ecosystem processes (Fig. 7)

Fig. 7: CUWA/Ag Technical Committee Recommended IEP Program Structure, 1995



Finally, several conceptual models were constructed as cause-effect matrices. The matrix approach was borrowed from B. Bernstein, “An Integrated Assessment Framework: Viewing Multiple Impacts.” These matrices did not directly refer to the EMP, but evaluated the state of knowledge and the importance of various measured constituents and environmental impacts in an ecosystem context.

The first matrix was created by an IESP monitoring evaluation committee in 1990 as a matrix of interactions between man-made and natural perturbations on the aquatic beneficial uses of the Bay-Delta estuary and their effect magnitudes on various aquatic constituents. From this the committee derived relative degrees of importance and understanding of the constituents or beneficial uses. Components with high degrees of importance would then be primary targets for monitoring and special studies.

The IEP Estuarine Ecology Team (EET) used the matrix approach in a 1995 report (IEP Technical Report 42) entitled “Working Conceptual Model for the Food Web of the San Francisco Bay/Delta Estuary.” With this model EET members attempted to describe and summarize their understanding of the Bay-Delta ecosystem and identify areas of uncertainty or ignorance. They created separate cause-effect matrices for upstream, downstream, and entrapment zone areas of the Bay-Delta ecosystem emphasizing lower trophic levels. The last matrix to date was published by the IEP EET in its 1997 report (IEP Technical Report 52) entitled “An Assessment of the Likely Mechanisms Underlying the “Fish-X2” Relationships.”

III. Program reviews and revisions.

During its 30-year existence the IEP EMP has experienced few substantial reviews and revisions. The only significant changes in its first 20 years were the revisions associated with the hearings and the enactment of D-1485 in 1978 described above. Otherwise the program remained largely unchanged. With the intensifying environmental activity in the Bay-Delta in the last 15 years, the EMP has recently received increased attention. Reviews of several EMP aspects as well as other IEP elements occurred, leading to a major EMP revision in 1995. The main goal of this revision was to streamline the existing program for more efficient budget and resource allocation. In January of 1996, DWR and USBR implemented a revised monitoring program. Revisions implemented included:

1. Modifying the historic D-1485 discrete sampling program from a semi-monthly to a monthly sampling program and consolidating the number of sites sampled.
2. Fully integrating the DWR/USBR water quality, phytoplankton, benthic and DFG zooplankton sampling programs.
3. Increasing the existing continuous, multi-parameter water quality monitoring network in key areas throughout the estuary to replace portions of the discrete sampling program.
4. Using state-of-the-art, on-board, continuous water quality monitoring equipment (SeaBird and Turner instruments) to provide vertical and longitudinal profiles at and between discrete (grab) sampling sites.
5. Allocating more funds to a more substantial “special studies” agenda to address specific concerns.

Table 6 summarizes the results of major reviews conducted in the last decade. With the exception of the most recent review (2000), all reviews were conducted through IEP. The1995 and 1996A reviews were more general than the other reviews and included reviews of IEP components other than the EMP. The 1994, 1992-94, and 1992 reports specifically targeted the EMP or parts thereof. The 1996B review evaluated the entire continuous monitoring network which includes the EMP multiparameter sites.

Table 6: Summary of recent reviews

Year	Author(s)	Document title	Document content	Impetus for creating document	Recommendations/New Goals	Implementation of recommendations
2000	Zachary Hymanson, Steve Hayes, Hank Gebhard (DWR-ESO)	DWR Compliance Monitoring Program for the Sacramento-San Joaquin Estuary	DWR Delta Water Quality Program Review	Evaluation of all of DWR's Bay-Delta WQ monitoring programs to improve coordination	1. Improve data management, dissemination, and reporting; 2. Maintain program relevance; 3. Collaborations/coordinated research; 4. Comprehensive programmatic review; 5. Integration with CALFED	Recommendations mainly achieved through formation of a DWR Office of Water Quality (will be established by 7/01)
1996A	Patrick Coulston, IEP Program Manager	Recommendations regarding comprehensive Aquatic Monitoring in the Sacramento-San Joaquin Estuary and its tributaries (IEP Technical Report 58)	Compilation of the results of a 3-day 1996 IEP workshop to identify key deficiencies in Bay-Delta aquatic monitoring	Program shortcomings, better use of limited resources	1. Systematic reviews of program elements every five years; 2. Evaluation of representativeness of sampling; 3. Integration of existing and future monitoring; 4. Implement systemwide monitoring (Bay, Delta and tributaries); 5. Comprehensive and ongoing analysis of existing water quality monitoring data by analysis team with the support of data base team.	1.-3. in progress 4. now being considered by CALFED; additional conceptual planning done via CMARP, but nothing new has been implemented yet. 5. Not implemented
1996 B	Ad-Hoc IEP committee to evaluate continuous monitoring sites	Committee recommendations	DWR&USBR evaluation of and recommendations for continuous monitoring sites (including non-EMP sites)	Acceptance of 1995 Bay-Delta plan which included reduction of discrete sites and increasing number of continuous sites	1. Improve coordination between DWR&USBR; 2. Provide more meaningful and consistent data base for users; 3. Eliminate duplicate sites	Little progress
1995	Leo Winternitz, DWR-ESO	Synopsis of recommendations for IEP monitoring and study revisions by IEP MT, SAG, and AG/CUWA	Summary of reviews by IEP Management Team, IEP SAG, and IEP Urban/Ag Teachnical Team, with summary table	Review of all IEP monitoring studies in response to new needs resulting from 1994 Bay-Delta Water Accord; Integration of recommendations from 3 teams for subsequent implementation	1. Improve data management, dissemination, and reporting ("big picture thinking") 2. Maintain comparability in methods; include SP Bay; 3. Develop a community based/ecosystem process monitoring program; 4. Consider ecological health in use of IEP data; 5. Develop formal peer review program; 6. Rely on Communication, collaboration, and coordination for a comprehensive monitoring program; 7. Establish Data Management PWT	1.slow but steady progress on IEP data base 2. San Pablo Bay stations added 3.-5. Not implemented 6. Attempted through CMARP 7. Interagency Information System Services in DWR-ESO (not a PWT)
1994	Zachary Hymanson, David Mayer, John Steinbeck	IEP Technical Report 38: Long-Term Trends in Benthos Abundance and persistence in the Upper Sacramento-San Joaquin Estuary. Summary Report 1980-1990	Multi-year report on benthic monitoring results combined with review of benthic monitoring program	Long-term analyses of benthic data; Review to determine and improve the ability of the benthic monitoring program to detect changes in benthic community structure	1. Continue monitoring trends and detect changes in abundance and distribution of the benthic fauna and providing baseline information for special studies 2. Collect samples for enumeration of benthic organisms at three existing and five new sites, drop five existing sites 3. Collect three samples per month at each site 4. Estimate organism biomass every other month 5. Summarize muti-year results and review benthic monitoring program every five years	1. In progress 2. Added five new sites, retained five existing sites 3. Now collect 4 replicate samples per site 4. Not implemented 5. Next report planned for 2001

Year	Author(s)	Document title	Document content	Impetus for creating document	Recommendations/New Goals	Implementation of recommendations
1992-1994	IEP staff/Ad hoc committee (USBR, DWR, DFG, and Wim Kimmerer, Tim Hollibaugh, Jerry Turner, others)	Proposed Baseline Monitoring Program for the San Francisco Bay-Delta Estuary	Description of revised baseline monitoring program to replace D-1485 (1978); with 4 technical appendices	Bay-Delta water rights hearings and 1993 IEP review recommendations for program revision: Make monitoring more effective and efficient and free up money for studies into non-project questions/mechanisms driving observed trends.	Streamlining! 1. Reduce discrete sites to the smallest possible number of representatives for geographic regions determined by cluster analysis; 2. Add more multi-parameter sites; 3. Add horizontal and vertical profiles to study stratification patterns & surface vs. bottom phenomena	Most implemented and incorporated in Bay-Delta Plan.
1992	IEP staff (Compiled by USBR)	Initial Draft Report – Proposed baseline water quality and biological monitoring program for the San Francisco Bay-Delta Estuary	Recommendations for a revised baseline monitoring program to replace D-1485 (1978);	Bay-Delta water rights hearings	1. Conduct an in-depth technical review of program 2. Central authority and funding source is needed to direct, monitor and control estuarine environmental monitoring and studies in order to better coordinate programs and assure quality and availability of data; 3. Instead of modifying the D-1485 program, a completely new monitoring program should be designed and then coordinated with the existing program to ensure continuity; 4. Previously not monitored but ecologically important parameters should be part of special studies (*e.g.*, microzooplankton, bacteria, biotoxicity, etc.); 5. Add more multi-parameter sites 6. Monitoring plan should be for Delta and Bay combined (“global perspective”)	1. and 5.: Implemented; 2., 3., 4., 6.: Not implemented.

The EMP reviews succeeded to varying degrees in prompting the recommended changes to the program. Most recommendations made in the recent EMP reviews were rather general in nature. Their lack of specificity may be part of the reason for the low implementation success. More specific recommendations which also include implementation strategies might have a greater chance of actual realization.

Overall, there were relatively few changes to the program. The streamlining effort of the mid-1990s resulted in the most noticeable program alterations. However, these changes did not correspond to changes in conceptual program design or objectives. The primary objective throughout the thirty-year history of the program has been to fulfill the legally mandated identification and reporting of changes in significant water quality parameters and planktonic organisms affected by CVP and SWP operations. The main objectives and consequently the design of the program were never based on questions of more general scientific relevance, although several reviews recommended such an approach. However, in spite of the very applied nature of the EMP, great amounts of data of immense scientific value have been accumulated over the years. As most reviews point out, analysis and synthesis of these data lag far behind their accumulation rate. While the program has faithfully delivered its legally mandated products in the form of annual reports, there have only been occasional analyses of the long-term records leading to more comprehensive and more scientifically relevant publications. Also, scientists outside of the EMP have not made very much use of the publicly available data, possibly because of the still limited access to the database. This is in spite of the fact that the EMP data could well be used to study ecological phenomena leading to insights similar to those gained through the NSF Long Term Ecological Research (LTER) Network. The stated mission of this world-renowned program is to facilitate and conduct ecological research through:

- Understanding ecological phenomena over long temporal and large spatial scales,
- Creating a legacy of well-designed and documented long-term experiments and observations for future generations, and
- Conducting major synthetic and theoretical efforts, and providing information for the identification and solution of ecological problems.

Furthermore, the LTER Network is committed to long-term ecological research on the following core areas:

- Pattern and control of primary production
- Spatial and temporal distribution of populations selected to represent trophic structures
- Pattern and control of organic matter accumulation and decomposition in surface layers
- Patterns of inorganic inputs and movements of nutrients through soils, groundwater and surface water

- Patterns and frequency of disturbances

The 2001 IEP EMP review should investigate the desirability of similar goals for the EMP and how to adapt the program to more specifically address these or similarly scientifically relevant questions without losing sight of the legally mandated program objectives.

IV. IEP EMP Resources, Budget, and Staffing

A. Resources:

1. Program Costs are shared by DWR and the USBR (i.e. the CVP and SWP permit holders).
2. Trained staff is provided to the program primarily by DWR and DFG with some help from the USGS.
3. The RV San Carlos, a 56 ft., fiberglass hulled research vessel owned and operated by DWR, is used for most discrete sampling. It is currently anchored in Antioch, where a small storage and office building are also available to the program. It houses a fully functional, covered laboratory/sampling preparation space equipped with flow-through instruments (Turner fluorometer and nephelometer, Sea-Bird probes), a vertical CTD unit (Sea-Bird), computers, and benches for filtration, titration, etc. All sample processing prior to analysis by the contract laboratories specified in Appendix 1 is completed on board. The rear deck space is conveniently designed for sampling with nets, Van Dorn samplers, sediment grabs etc. It includes an A-frame and various winches and water hoses. In addition to lab and sampling space, the San Carlos also has a kitchen, living, and sleeping area and a large bridge. The vessel is used for monitoring purposes 7 to 10 full days per month.
4. A second, smaller, but similarly equipped research vessel (RV Compliance) owned by the USBR serves as a back-up boat for the San Carlos.
5. A DWR lab van is available for sampling of discrete sites inaccessible by boat. The van is used for monitoring purposes one day per month.
6. The multi-parameter shore site equipment is housed in small, usually air-conditioned sheds. All sheds offer enough space for equipment maintenance and are flood-proof.
7. The DWR office building in Sacramento contains a very limited amount of laboratory space. This space is primarily used for instrument maintenance and for processing samples associated with special studies.
8. Chemical and chlorophyll sample analysis is conducted by DWR's Bryte Chemical Laboratory ("Bryte Lab," Bill Nickels, Director) in West Sacramento. This laboratory was established in 1951 and has maintained certification by the Environmental Protection Agency and the California Department of Health Services for water analysis since 1978.

B. Current budget and Personnel

Currently, the total budget for all USBR/DWR/DFG environmental monitoring activities is close to three million dollars. Of this amount, 28% are contributed by the USBR while the remaining amount is funded by DWR. 6% are transferred to DFG for *Neomysis*/zooplankton work. The following tables detail operational and personnel expenses.

Table 7: Current Program Costs

Category	Cost
Administration and Program Management	$247,600.-
Field work and equipment maintenance	$1462,000.-
Data reduction and analysis	$866,000.-
Multi-parameter recorder operation	$330500.-
Total:	**$2,906,100.-**

Table 8: Current Personnel

Classification	Agency	Staff Commitment	Location	Name
Environmental Program Manager	DWR	50%	Office	Zach Hymanson
Environmental Specialist IV (Supv)	DWR	100%	Office	Steve Hayes
Environmental Specialist IV	DWR	100%	Office	Peggy Lehman
Environmental Specialist III	DWR	50%	Office	Anke Mueller-Solger
W.R. Engineering Associate	DWR	100%	Office, Field	Katherine Triboli
Environmental Specialist II	DWR	100%	Office, Field	Cindy Messer
Environmental Specialist I	DWR	100%	Office, Field	Casey Ralston
W.R. Tech I	DWR	100%	Office, Field	Scott Waller
F & W Scientific Aid	DWR	75%	Office, Field	Karen Gehrts
Student Assistant	DWR	Variable	Office, Field	Shaun Phillipart
Chief Boat Operator	DWR	100%	Field	Lloyd Brenn
Asst. Boat Operator	DWR	75%	Field	Eric Santos
Sr. Control Eng. (Supv)	DWR	100%	Office, Field	Hank Gebhard
Control Systems Tech II	DWR	100%	Office, Field	Mike Dempsey
Control Systems Tech I	DWR	100%	Field	Vacant
Control Systems Tech I	DWR	75%	Field	Jay Aldrich
Student Assistant	DWR	50%	Office	Shaun Philippart

Classification	Agency	Staff Commitment	Location	Name
Environmental Program Manager	DWR	50%	Office	Zach Hymanson
Environmental Specialist IV (Supv)	DWR	100%	Office	Steve Hayes
Environmental Specialist IV	DWR	100%	Office	Peggy Lehman
Environmental Specialist III	DWR	50%	Office	Anke Mueller-Solger
W.R. Engineering Associate	DWR	100%	Office, Field	Katherine Triboli
Environmental Specialist II	DWR	100%	Office, Field	Cindy Messer
Associate Marine Biologist	DFG	25%	Field	Lee Mecum
Environmental Scientist	USGS	25%	Field	Vacant

APPENDIX 1

The legal history of the IEP Environmental Monitoring Program

(Expanded version of Chapter II. B., main document)

In contrast to other long-term monitoring and research programs such as the National Science Foundation's long-term ecological research (LTER) program, environmental water quality monitoring in the Bay-Delta is mandated by and intricately linked with the law. While the Bay-Delta water quality monitoring program has produced valuable scientific insights into general estuarine ecology and hydrodynamics, its original purpose is to provide information for effective resource management and compliance with water quality standards set by state law. Its current design can only be understood and evaluated with this legal background in mind. The following section will give a historic overview of the pertinent laws. Table 1 gives a timeline of the most important events in the legal history of the IEP EMP.

With the construction and completion of major parts of the CVP and SWP in the late 1950's and the 1960's as well as a growing national awareness of water issues, Delta water quantity and quality became major issues of concern for agencies and users. This prompted legislative action. In the face of strongly increasing export demands, the first problem was maintaining sufficient amounts of water in the Delta. Addressing this concern, the state legislature passed the Delta Protection Act of 1959 to ensure adequate water supplies for Delta users. This act was passed during the same legislative session as the Burns-Porter Act which authorized and provided funding for the SWP.

Water quality concerns were addressed next. Before legislation regarding water quality was enacted by the State of California, the federal government had already begun addressing this issue. The federal involvement was spurred by increasing pollution problems as well as by a slow paradigm shift from ingrained ideas about the beneficial effects and necessity of reclamation projects to concerns about their effects on ecosystems. In 1948, the Federal Water Pollution Control Act, which later evolved into the Clean Water Act, authorized the U.S. Surgeon General to prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters. In 1950, the US Public Health Service issued the "Suggested State Water Pollution Control Act" recommending the establishment of water quality standards and water classifications through State Board orders involving public hearings. Adherence to these standards necessitated appropriate water quality assessment plans. Eventually, both standards and assessment plans were included in state and federal legislation. In 1960, Congress recognized that the primary responsibility for water quality protection should rest with the states. The federal role in water quality protection was to provide technical services and financial assistance to the states. In 1966, the Clean Water Restoration Act (a revision of the 1948 Federal Water Pollution Control Act) authorized federal agencies to conduct a comprehensive study of the effects of pollution on estuarine ecology and various specified uses.

In California, these federal activities led to early water quality surveys such as the Delta-Suisun Bay Surveillance Program, as well as the establishment of the State Water Pollution Control Board (SWPCB) and its regional boards in 1949. The SWPCB was charged with the coordination of water pollution control and later became the State Water Quality Control Board (SWQCB). Taking up ideas from the federal Suggested State Water Pollution Control Act of 1950, the newly formed SWPCB soon commenced investigation and formulation of suitable water quality standards with the help of the California Institute of Technology. This resulted in a widely circulated and nationally and internationally acclaimed 1952 SWPCB publication entitled “Water Quality Criteria.” However, for more than a decade thereafter, California did not adopt statewide or even regional water quality standards. Instead, potential or existing pollution problems were studied and regulated by the regional boards on a case-by-case basis.

A first step toward regional legislative regulation for the Bay-Delta was an agreement by DWR, USBR, the Sacramento and Delta Water Association, and the San Joaquin Water Rights Committee on interim water quality criteria for TDS and chlorides and their assessment in November 1965. This agreement came to be known as the “November 19th Agreement” and represents one of the earliest interagency agreements on water quality standards and monitoring in California. The agreement included 10 monitoring stations throughout the Delta (s. II B Fig. 2). The salinity standards and the “November 19th Criteria Stations” were subsequently included in State Water Right Decision D-1275 of 1967 which approved water rights for the SWP. As a result, this decision became the first California decision to contain water quality standards. However, the scope of these standards was limited to salinity and did not encompass standards for the protection of fish and wildlife, pollution control, etc.

Later in 1967, the California State Water Resources Control Board (SWRCB) was created through a fusion of the SWQCB and the State Water Rights Board for the dual purpose of determining water rights and regulating water quality. Under the Porter-Cologne Water Quality Control Act (Porter-Cologne) of 1969, the SWRCB was granted the ultimate authority over State water rights and water quality policy. Regional Water Quality Control Boards were to oversee day-to-day water quality management at the regional level and were charged with the preparation and periodic updating of regional water quality control plans (Basin Plans). These plans were to establish beneficial uses of water to be protected, ground- and surface water quality standards (called water quality objectives), and actions necessary to maintain these standards. According to the California Water Code, a water quality objective is defined as "the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area" (Wat. Code §13050(h)). Further, "Quality of the water" is defined as the "chemical, physical, biological, bacteriological, radiological, and other properties and characteristics of water which affect its use." (Wat. Code §13050(g)). Basin plans set forth water quality terms and conditions to be used in water right decisions permitting water development plans.

The first Basin Plan for the Sacramento-San Joaquin Delta ("Sacramento-San Joaquin Delta Water Quality Control Plan") was completed in 1975. It contained a set of water quality standards resembling requirements in SWRCB Water Right Decision D-1379. This 1971 decision concerned water rights for the SWP and CVP. As part of the permits for these projects, D-1379 specified mandatory water quality standards and for the first time outlined a comprehensive compliance water quality monitoring program for the Delta. It listed 32 monitoring stations including nine of the ten "November 19th Criteria Stations" and 23 categories of parameters to be measured. Stations and variables were selected based on recommendations by a Stanford Research Institute study commissioned by SWRCB and published in 1970, as well as by proximity to sites sampled in previous studies (the "C", "D", "S", and "P" sites established in the Delta-Suisun Bay Surveillance Program and the "November 19th Criteria Stations").

D-1379 and the 1975 Basin Plan were superceded in 1978 by D-1485 and the "Water Quality Control Plan for the Sacramento-San Joaquin Delta and the Suisun Marsh" (the "1978 Plan" or "Delta Plan"). Both documents augmented and revised previous water quality standards related to salinity control and fish and wildlife protection via flow regulation. D-1485 standards were based on the potential degree of protection that municipal, industrial, agricultural, and fish and wildlife uses would have experienced in the absence of the SWP and CVP. The SWP and CVP agencies were ordered to make operational decisions aimed at maintaining Delta water quality and specified flows. D-1485 also added fisheries monitoring in San Francisco Bay and Suisun Marsh monitoring to the compliance monitoring program. It identified 44 water quality monitoring stations including 24 of the D-1379 station and six groups of variables. In addition to monitoring, D-1485 also required special studies to provide critical data in areas of scientific uncertainty. In case of new evidence of detrimental project effects and changes in environmental conditions, D-1485 specified that Delta water right permit hearings should be reopened. However, in spite of being challenged by various lawsuits, D-1485 remained in effect for almost thirty years.

Instrumental in retaining D-1485 and paving the way for more comprehensive protection measures was the 1986 appellate court " Racanelli Decision" (after Judge Racanelli). This decision broadly reaffirmed the SWRCB's authority to establish water quality objectives and set terms and conditions for water rights permits that protect beneficial uses of Delta water and of San Francisco Bay. It also said that all beneficiaries of water destined for the Delta must share responsibility for meeting flow and water quality standards for the Delta.

According to the Racanelli Decision, water quality regulation and the protection of beneficial uses should be more comprehensive than just pollution control. Another important event of 1986 was the “Coordinated Operation Agreement” signed by USBR and DWR. According to this agreement, the two agencies had to coordinate project operation to meet D-1485 standards and share the limited water resources equitably.

Shortly after these events, several phases of hearings began for a new water quality control plan and a new water right decision for the entire Bay-Delta complex including San Francisco Bay. These documents were supposed to significantly update standards for the protection of beneficial uses of the estuary and supercede previous acts. A water quality control plan adopted by SWRCB in 1991 was partly rejected by the US EPA because of inadequate standards aimed at the protection of fish and wildlife. The following years saw intense activity on the state and federal level. These activities included the separate announcements of proposals for revised standards by SWRCB and by the US EPA in 1992, and the listing of several fish species in the estuary as threatened or endangered according to the Endangered Species Act in 1993. Subsequently, SWRCB and the US EPA commenced negotiating mutually acceptable standards. In 1994, the California Water Policy Council (CAL) and the Federal Ecosystem Directorate (“Club FED”) signed an interagency framework agreement to improve coordination and communication among agencies in order to achieve long-term solutions to the estuary's problems. This effort soon became known as the “CALFED” process to address environmental and water management problems associated with the Bay-Delta system. CALFED was officially launched by Governor Pete Wilson and the Clinton administration in 1995.

Meanwhile in 1994, State and federal officials announced their agreement on comprehensive Bay-Delta standards ("Bay-Delta Accord") which paved the way for the adoption of a more widely accepted new Water Quality Control Plan for the Bay-Delta in May 1995 (“Bay-Delta Plan”). As part of the hearings process for this plan, DWR and USBR with the help of IEP conducted an extensive review of the D-1485 Environmental Monitoring Program. This plan sets standards for salinity (chloride and electrical conductivity (EC)), dissolved oxygen (DO), flow, and water project operations at 28 stations. To comply with the standards, the listed variables had to be regularly monitored at these 28 stations (“compliance monitoring stations”). In addition, the Bay-Delta Plan identified 15 stations for “baseline monitoring” and mandated a special studies program in order to “increase understanding of the large-scale characteristics and functions of the Estuary ecosystem to better predict system-wide responses to management options.”

In June 1995 SWRCB issued water rights order WR 95-6. This order temporarily amended terms and conditions of D-1485 to meet the new standards set forth by the Bay-Delta Plan. The revised monitoring plan contained in this order was implemented starting in January 1996. WR 95-6 was amended in SWRCB Order 98-09 of 1998. Finally, a new water right decision, D-1641, was adopted in December 1999 and revised in March 2000. It contains the standards and monitoring plan with stations and parameters specified in the Bay-Delta Plan.

Table 1: Major developments concerning Bay-Delta environmental monitoring.

YEAR	EVENT
1902	Creation of the US Bureau of Reclamation to assist in settling the arid west by providing water storage and delivery facilities to irrigate family farms
1920	Initiation of regular salinity monitoring in the Delta
1927	Creation of Division of Fish and Game within the Department of Natural Resources
1927	Law enabling state to obtain water rights to implement water resource development plans. Immediately thereafter: acquisition of rights to surplus waters by state - start of water rights decisions involving state and federal water projects
1931	State Engineer publishes results of 10-year salinity control study with summary of major Central Valley Project (CVP) features and recommended outflows
1933	California legislature authorizes **CVP** to transfer Sacramento Valley water to San Joaquin Valley and the Bay Area, and provide for flood control, navigation, power, recreation and fisheries, and salinity control
1944	Shasta Dam completed (Sacramento flow regulation -> salinity control)
1948	Federal Water Pollution Control Act (=1st federal comprehensive legislation on pollution control)
1949	CA Water Pollution Act for surface and groundwater pollution and water quality control in California based on "Dickey Report"; added as Div. 7 to CA water code; established **State Water Pollution Control Board (SWPCB)** and Regional Boards
1950	US Public Health Service issues "Suggested State Water Pollution Control Act" which recommends the establishment of water quality standards and water classifications through State Board orders and after public hearings (used by 40 states in 1961)
1951	Division of Fish and Game elevated to departmental status, **DFG**
1951	Completion of the CVP Delta-Mendota Canal and construction of the Delta Cross Channel
1952	SWPCB Pub. 3A "Water Quality Criteria" - Literature review and critical evaluation of nation-wide water quality criteria to serve as a guideline for setting water quality standards. Prepared under contract by California Institute of Technology
1955	SWP with assistance by Board of Consultants recommends limits for several minerals
1956	Creation of the Department of Water Resources (**DWR**) from State Engineer's Office, the Water Project Authority, the State Water Resources Board, and the Division of Water Resources of the Department of Public Works. Water rights jurisdiction is assigned to another new agency--the **State Water Rights Board**.

1957	California Water Plan (DWR Bulletin No. 3). It presents preliminary plans for developing all of the state's water resources to meet its ultimate water needs and outlines the SWP.
1959	CA state legislature passes **Delta Protection Act** to assure adequate water supplies for Delta water users in the face of increasing water exports to Southern California
1959	CA state legislature passes **Burns-Porter Act** (CA Water Resources Development Bond Act) to assist in financing state water resources development system (includes SWP) to meet growing water demands
1960	California voters approve **Burns-Porter Act** and thus **SWP**
1961	DFG and DWR "Delta Fish and Wildlife protection study" (fish and wildlife habitat requirement study)
1961	Water Right Decision **D 990**: First permits for Project operations
1965	"Interagency Delta Committee" recommends Delta facilities (including peripheral canal) to offset effects of increasing exports

YEAR	EVENT
1965	**"November 19th Agreement"** between DWR, USBR, Sacramento and Delta Water Associations and the San Joaquin Water Rights Committee on interim criteria upon which to base Delta outflows to protect and ensure water quality (TDS & Cl- agreement includes ten "criteria stations")
1966	**US Clean Water Restoration Act**: 1966 amendments to Federal Water Pollution Control Act; Authorized the Secretary of the Interior to conduct a comprehensive study of the effects of pollution, including sedimentation, in the estuaries of the U.S. on fish and wildlife, sport and commercial fishing, recreation, water supply and power, and other specified uses
1967	Creation of the Sate Water Quality Control Board (**SWRCB)**. Combines functions of SWQCB (water quality control)and State Water Rights Board (water rights).
1967	DWR assumes additional responsibilities of flood control, construction of water facilities, and dam safety
1967	State of California submits water quality standards for interstate and navigable waterways (including the Delta) to the Federal Government
1967	SWRCB water right decision **D1275**: establishes interim conditions for the protection of fish and wildlife and salinity control and conditionally approves DWR applications for the SWP
1968	DWR and USBR "Delta-San Luis Drain Surveillance Program" (water quality monitoring, "D" stations)
1968	Start of *Neomysis*/zooplankton sampling by DFG
1969	**Porter-Cologne** Water Quality Control Act (SWRCB) passed by the California legislature

1970	First Earth Day
1970	Creation of **US EPA**
1970	NEPA and CEQA signed into law
1970	California's Clean Water Bond Act
1970	SWRCB environmental monitoring program plan completed by SRI in response to environmental concerns expressed during water rights hearings
1970	Formation of **IEP** (then called Interagency Ecological Study Program, **IESP**) through an MOU between USBR, USFWS, DWR, CDFG to coordinate environmental studies in the Delta and Suisun Bay and to carry out 12 specific studies and monitor water quality
1971	**D-1379**: First water rights decision requiring USBR and DWR to conduct compliance monitoring/water quality studies
1972	National Clean Water Act (**CWA**) (=Federal Water Pollution Control Act of 1972, successor of 1948 Act) controls pollutant discharge into surface waters (Federal Version of the Porter-Cologne Water Quality Control Act)
1973	Federal Endangered Species Act passed by Congress
1973	California Aqueduct completed to Southern California
1974	**Federal Safe Drinking Water Act**, sets national standards for drinking water quality
1975	First “Basin Plan” for the Delta, the “Sacramento-San Joaquin Delta Water Quality Control Plan” It provided for protection of the Delta's varied beneficial water uses through a set of water quality objectives similar to requirements in D-1379
1978	**SWRCB Water Quality Control Plan for the Delta and Suisun Marsh**
1978	**D-1485**: Revision of monitoring program to include fisheries monitoring in SF Bay and expansion of water quality monitoring. This plan remained in effect through 1995.
1982	Peripheral canal and other statewide facilities rejected by California voters
1985	USGS and SWRCB become IEP members
1985	Field study expansion to include hydrodynamic studies in SF and SP Bays
YEAR	EVENT
1986	Initiation of construction of the Suisun Marsh Salinity Control Gates, which increased the amount of fresh water flowing into the marsh to preserve it as the largest contiguous brackish water marsh remaining in the U.S. The gates are declared operational on November 22, 1989.
1986	DWR and DFG "4-Pumps Agreement" (referring to the four additional pumps to be installed at the SWP Pumping Plant) to offset the direct losses of striped bass, chinook salmon and steelhead caused by the SWP pumping plant's operation.
1986	First CVP-SWP Coordinated Operation Agreement (DWR and USBR

	Accord) to cooperatively operate the CVP and SWP
1990	US COE, SF District Office, and US EPA, Region 9, become IEP members
1991	Official integration of ongoing physical/chemical and phytoplankton elements into IEP minitoring program
1992	CA state legislature passes **"Delta Protection Act**" establishing the Delta Protection Commission to develop a comprehensive, long-term resources plan for the Delta by July 1, 1994.
1992	Congress passes the **Central Valley Project Improvement Act (CVPIA)** establishing the "protection, restoration, and enhancement of fish, wildlife and associated habitat" as a project purpose of the CVP, and specifies a list of activities to be undertaken by the Secretary of the Interior
1993	IEP reorganization; Review of the IEP Study Program and recommendations for its revision
1994	Revised Water Quality Monitoring Program plan completed by IEP staff
1994	(June) Interagency Framework agreement to improve coordination and communication to achieve long-term solutions to the Estuary's problems (i.e. start **CALFED**)
1994	(Dec.) Interagency "**Bay-Delta Accord**" on Bay-Delta WQ standards to be implemented by SWRCB
1995	SWRCB Water Quality Control Plan for the Bay-Delta WR 95-6 ("**Bay-Delta Plan**") superseding D-1485 and the 1991 salinity control plan (comprehensive monitoring changes approved 12/15/1995)
1995	CALFED officially launched by Governor Pete Wilson and the Clinton administration
1995	Recommendations for IEP program revisions by the IEP management team, the science advisory group, and the agricultural/urban technical committee
1996	DWR and USBR begin implementing revised compliance monitoring
1996	Evaluations of continuous monitoring sites
1996	First Multi-Year DWR water quality report, 1970-1993
1997	Establishment of the IEP Water Quality PWT (Chair Jon Burau) and initiation of next monitoring program programmatic review
1998	Extension of SWRCB WQ control plan WR 95-6: Order WR 98-09
1999	Internal DWR review of all DWR water quality programs
1999	Water Right Decision 1641 issued by the SWRCB
2000	Revision of Water Right Decision 1641

APPENDIX 2

Description of the IEP Environmental Monitoring Program Design

Contents:

I. INTRODUCTION

The IEP Environmental Monitoring Program (EMP) is mandated by the SWRCB as an ongoing program to assess compliance with terms and conditions in the SWP and CVP water right decision. The following sections describe the current protocols for data collection, reduction, storage, analysis, verification, and reporting as well as procedures for on-board sample preparation and analysis. Most sample analyses are carried out by contract and service laboratories. Information on these laboratories and their procedures is also included in this section.

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II. DATA COLLECTION

A. Sampling

1. Discrete (boat or van) sampling

Discrete sampling occurs monthly at set sites in 9 geographic regions (Tables 1 and 2) using equipment and glassware cleaned according to cleaning techniques specified in the DWR *Sampling Manual for Environmental Measurement*. Samples are generally collected without duplication except when specified by a monthly rotational schedule for quality control purposes. Most sampling is conducted with the DWR-owned RV San Carlos. A lab van is used for two sites (C3 and C10). Van sampling is less comprehensive than boat sampling. For detailed on-board procedures see VI.

a) Discrete, on-site monitoring of physicochemical constituents: Water samples are collected at 1 meter depth as closely within 1 hour of high slack tide as possible using a Van Dorn sampler or a submersible pump. The time of each sample is recorded to the nearest 5 minutes using Pacific Standard Time. Water column depth, water temperature, and secchi disk depth are also recorded. Water samples are collected for laboratory measurement of the following constituents: silica, dissolved solids, volatile solids, total suspended solids, chloride, total (Kjeldahl) nitrogen, dissolved organic nitrogen, orthophospate, phosphorus, ammonia nitrogen, nitrite/nitrate, and phytoplankton. In addition, vertical and horizontal profiles are conducted monthly at sites sampled by boat for the following constituents: water temperature, dissolved oxygen concentration, specific conductance, turbidity, and chlorophyll *a* concentration. Measurement methods are referenced in Table 3.
b) Chorophyll *a* samples are filtered onto Gelman Type AE glass fiber filters and frozen for later spectrophotometric analysis.

c) Zooplankton sampling is conducted at the zooplankton sampling sites by DFG staff using a *Neomysis* net, a Clarke-Bumpus net (larger zooplankton) and a pump (microzooplankton). From 1968 through 1970 the *Neomysis* net was made of 1 mm silk bolting cloth, was 1 m long and had a mouth area of 0.1 m^2. From 1971 through 1973 the *Neomysis* net was made of 0.93 mm mesh nylon cloth, had a 30 cm mouth diameter and was 0.7 m long. From 1994 to the present, the mesh size has been 0.505 mm, the mouth diameter 30 cm and the length 1.48 m. All *Neomysis* nets tapered to 76 mm at the cod end where a polyethylene jar screened with 0.505 mesh wire cloth captured the Mysids. The Clarke-Bumpus net is made of 154 μm mesh nylon cloth (No. 10 mesh), has a mouth diameter of 10 cm, and a length of 73 cm. It tapers to 45 mm at the cod end. The organisms are concentrated in a stainless steel bottle with a screened opening. The nets are mounted on a tubular steel frame. The Clarke-Bumpus net is mounted directly above the *Neomysis* net. Until 1973, Pygmy flow meters were used to estimate water volumes filtered by the *Neomysis* net. From 1974 to present General Oceanics model 2030 flow meters have been used. The pump has a capacity of 15 l/min and was connected to a 15 m long hose which has a weighted nozzle at the lower end. The nets are towed from bottom to surface in a stepwise oblique tow lasting ten minutes. Microzooplankton are taken at the end of the tow by pumping several liters of water into a 19 l carboy while the hose is raised from bottom to surface. The carboy is shaken and a 1.5 to 1.9 liter subsample drawn. Samples are preserved in 10% formalin with Rose Bengal dye added to aid in separating the animals from detritus and algae. Zooplankton identification and enumeration is completed in the DFG laboratory in Stockton.

d) Vertical and horizontal profiles are also conducted monthly at all zooplankton tow sites for the following constituents: water temperature, dissolved oxygen concentration, specific conductance, turbidity, and chlorophyll *a* concentration.

e) Additional zooplankton tows are conducted at Stations NZ325, NZ02, and NZ04 when surface specific conductance values are below 20,000 S.

f) Four replicate benthic samples are collected at 10 stations on a monthly basis along with one sample for sediment composition analysis. Sample material is washed over a 0.5-mm mesh screen and the remaining material and organisms are sent to a laboratory for identification and enumeration.

g) Dissolved oxygen monitoring along the Stockton Ship Channel is conducted in the fall as a special monitoring study to document and evaluate the commonly occurring oxygen depletion in this area.

Table 1: Current sampling Station Locations, Discrete and Continuous Multi-Parameter Sampling

Station No.	Description	Latitude	Longitude	Region Represe n-tative[7]	Dis-crete[1]	Contin -uous[2]	Multi-para-meter[3]	Phyto-plankto n[4]	Zoo-plankto n[4,5]	Bentho s[6]
70	Sacramento River @ Hood	38§ 22' 02"	121§ 31' 13"				*			
C3	Sacramento River @ Greens Landing	38§ 20' 45"	121§ 32' 42"	ND	*			*		
C7	San Joaquin River @ Mossdale Bridge	37§ 47' 11"	121§ 18' 22"				*			
C9	West Canal at mouth of CC Forebay Intake	37§ 49' 50"	121§ 33' 09"							*
C10	San Joaquin River near Vernalis	37§ 40' 34"	121§ 15' 51"	SD	*			*		
D4	Sacramento River above Point Sacramento	38§ 03' 45"	121§ 49' 10"	LS	*			*	*	*
D6	Suisun Bay @ Bulls Head nr. Martinez	38§ 02' 40"	122§ 07' 00"	SB	*		*	*	*	*
D7	Grizzly Bay @ Dolphin nr. Suisun Slough	38§ 07' 02"	122§ 02' 19"	SB	*			*	*	*
D8	Suisun Bay off Middle Point nr. Nichols	38§ 03' 36"	121§ 59' 20"	SB	*			*	*	
D10	Sacramento River @ Chipps Island	38§ 02' 47"	121§ 55' 02"				*		*	
D12	San Joaquin River @ Antioch Ship Channel	38§ 01' 15"	121§ 48' 28"				*		*	
D16	San Joaquin River @ Twitchell Island	38§ 05' 50"	121§ 40' 05"						*	*
D22	Sacramento River @ Emmaton	38§ 05' 04"	121§ 44' 17"						*	
D24	Sacramento River below Rio Vista Bridge	38§ 09' 27"	121§ 41' 01"				*			*
D26	San Joaquin River @ Potato Point	38§ 04' 40"	121§ 34' 00"	LSJ	*			*	*	
D28A	Old River opposite Rancho Del Rio	37§ 58' 14"	121§ 34' 19"	CD	*			*	*	*
D29	San Joaquin River @ Prisoners Point	38§ 03' 32"	121§ 33' 23"			*				
D41	San Pablo Bay near Pinole Point	38§ 01' 50"	122§ 22' 15"	SPB	*			*		*
D41A	San Pablo Bay nr. Mouth of Peteluma R.	38§ 03' 75"	122§ 24' 40"							*
P8	San Joaquin River @ Buckly Cove	37§ 58' 42"	121§ 22' 55"	SD	*		*	*	*	*
MD10	Disappointment Slough near Bishop Cut	38§ 02' 38"	121§ 25' 04"	ED	*			*	*	
S42	Suisun Slough 300' south of Volanti Slough	38§ 10' 50"	122§ 02' 45"						*	
NZ032	Montezuma Slough, 2nd bend from mouth	38§ 10' 17"	122§ 01' 03"						*	
NZ325	San Pablo Bay near Rock Wall and Light 15	38§ 03' 28"	122§ 17' 20"						*	
NZ02	Carquinez Strait near Glen Cove	38§ 03' 37"	122§ 12' 25"						*	
NZ04	Ozol near Martinez and Light 25	38§ 01' 45"	122§ 09' 30"						*	
EZ2	Entrapment Zone - Location determined when bottom EC values occur at approximately 2000 s	Variable	Variable						*	
EZ6	Entrapment Zone - Location determined when bottom EC values occur at approximately 6000 s	Variable	Variable						*	

1. Physicochemical constituents, monthly at set Stations. Constituents: Water column depth, secchi disk depth, nutrient series (inorganic and Organic N-P), water temperature, dissolved oxygen concentration, specific conductance, turbidity, chlorophyll a concentration. Also: vertical and horizontal profiles, monthly, for: water temperature, dissolved oxygen concentration, specific conductance, turbidity, and chlorophyll a concentration.
2. Water temperature and specific conductance are monitored continuously at Station D29 from April-May.
3. Continuous multi-parameter monitoring, provides telemetered data, constituents: water temperature, dissolved oxygen concentration, specific conductance, wind speed and direction, solar radiation, air temperature, pH, and tidal elevation. Solar radiation, air speed and direction are not collected at Stations C7 and 70. Chlorophyll a concentration is measured continuously at Stations D24 and P8 year-around and at Stations D10 and D12 from March – October.

4. Sampling occurs monthly at discrete sites.
5. In addition to compliance sites, zooplankton tows at Stations NZ325, NZ02, and NZ04 are conducted when surface specific conductance values are below 20,000 us. Vertical and horizontal profiles are also conducted monthly at all zooplankton tow sites for the following constituents: water temperature, dissolved oxygen concentration, specific conductance, turbidity, and chlorophyll a concentration.
6. Replicate benthic samples are collected at 10 stations on a monthly basis along with one sample for sediment composition analysis.
7. Stations representing regions based on cluster analysis, s. Table 2

Table 2: Regions of sampling station locations (according to cluster analyses conducted by DWR to reduce sampling sites from formerly 26 discrete boat/van sites to the current 11 sites in Table 4)

Index	Region description
ND	Northern Delta
SD	Southern Delta
LS/WD	Lower Sacramento River/Western Delta
SB	Suisun Bay
LSJ	Lower San Joaquin River
CD	Central Delta
SPB	San Pablo Bay
SD	Southern Delta
ED	Eastern Delta

Table 3: Current Analyses, discrete (boat or van) sampling.

Variable	Field and Lab Analysis	Units	Analysis by[1]	Method[2]
Chemical	Total Suspended Solids (TSS)	mg/L	Bryte Lab	EPA 160.2
Chemical	Volatile Suspended Solids (VSS)	mg/L	Bryte Lab	EPA 160.4
Chemical	Todal Dissolved Solids (TDS)	mg/L	Bryte Lab	SM 2540-C
Chemical	Total Organic Nitrogen	mg/L	Bryte Lab	EPA 351.2
Chemical	Dissolved Organic Nitrogen	mg/L	Bryte Lab	EPA 351.2
Chemical	Dissolved Ammonia	mg/L as N	Bryte Lab	EPA 350.1
Chemical	Dissolved Nitrite + Nitrate	mg/L as N	Bryte Lab	Mod. SM 4500-NO3-F
Chemical	Total Kjeldahl Nitrogen	mg/L as N	Bryte Lab	EPA 351.2
Chemical	Total Phosphorus	mg/L	Bryte Lab	EPA 365.4
Chemical	Dissolved Ortho-Phosphate	mg/L as P	Bryte Lab	Mod. EPA 365.1
Chemical	Dissolved Chloride	mg/L	Bryte Lab	EPA 325.2
Chemical	Dissolved Silica (SiO2)	mg/L	Bryte Lab	SM 4500-Si-D
Biological	Chlorophyll a, discrete (spectrophotometric)	µg/L	Bryte Lab	SM 10200H
Biological	Pheophytin a, discrete (spectrophotometric)	µg/L	Bryte Lab	SM 10200H
Pedological	Sediment (benthic sites) – organic content	%	Bryte Lab	ASTM D2974-87
Pedological	Sediment (benthic sites) – particle size anal.	%	Bryte Lab	ASTM D422-63
Biological	Chlorophyll a, continuous, on-board, fluorometric	µg/L	RV Crew	
Chemical	Dissolved Oxygen, Winkler	mg/L	RV Crew	
Chemical	Dissolved Oxygen, Sea Bird and YSI Probes	mg/L	RV Crew	
Physical	Water Temperature	oC	RV Crew	
Chemical	Turbidity	NTU	RV Crew	
Physical	Secchi	cm	RV Crew	
Chemical	Specific Conductance	µS/cm	RV Crew	
Physical	Water Depth	Feet	RV Crew	
Physical	Sample Depth	Feet	RV Crew	
Physical	Time	PST	RV Crew	
Biological	Benthos composition and abundances		Hydrozool.	
Biological	Phytoplankton composition and abundances		DWR Staff	
Biological	Zooplankton composition and abundances		DFG Staff	

1 Bryte Lab: DWR Bryte Chemical Laboratory, Bill Nickels, Director.
RV Crew: DWR-ESO, DFG, and USGS staffing San Carlos and Compliance
Hydrozool: Hydrozoology Laboratories, Newcastle, CA (Contract laboratory)

2 EPA, APHA Standard Methods (SM), and American Society for Testing and Materials (ASTM), some with DWR-Bryte Lab modifications (Mod.)

2. Continuous (shore station) sampling

a) Multi-parameter monitoring is conducted continuously and provides telemetered data for the following constituents: water temperature, dissolved oxygen concentration, specific conductance, wind speed and direction, solar radiation, air temperature, pH, and tidal elevation (Table 4). Solar radiation, air speed and direction are not collected at Stations C7 and 70. Chlorophyll *a* concentration is measured continuously at Stations D24 and P8 year-around and at Stations D10 and D12 from March – October.

b) Water temperature and specific conductance are monitored continuously at Station D29 from April-May.

Table 4: Current Analyses, continuous multi-parameter (shore-station) sampling.

Variable	Continuous Measurements[1]	Units
Chemical	Dissolved Oxygen	mg/L
Chemical	Specific Conductance	µS/cm
Chemical	pH	unit pH
Physical	Water Temperature	°C
Physical	Air Temperature	°C
Physical	Wind Speed	KPH
Physical	Wind Direction	
Physical	Solar radiation	cal/cm2/min
Physical	River stage elevation	MSL
Biological	Chlorophyll a (Fluorometric)	Fluo. Units

B. Sample processing

1. Preparation

a) Dissolved Constituents: Millipore Low Water Extract filters (0.45mm pore size) are soaked in distilled water for at least one half hour before use. Filters are handled with clean forceps. The soaked filters are then set on a filtering apparatus, and about 25mls of distilled water is filtered. The filtrate is discarded and labeled sample bottle are attached to the filtering apparatus. A small amount of sample is filtered into the sample bottles. The filtrate is again discarded, and approximately 200mls of sample are filtered into the sample bottles. Samples are stored frozen or refrigerated according to parameter requirements (Table 5) until further processing.

b) Total or Particulate Constituents: Fill one 250ml bottle with sample water to within one inch from the top to allow for expansion upon freezing. Fill a second bottle, either a pint or a quart full of sample water. One quart sample per day is collected for QA/QC for Bryte Lab. The site designated for the larger sample is shown on the Q/A quart sample schedule.

c) Chlorophyll a samples are drawn onto Gelman Type AE glass fiber filters (see procedure below).
d) Phytoplankton samples are collected in 4 oz. glass bottles and preserved with 1 ml of Lugol's Iodine Solution.
e) On a field sheet, date, time and depth of the sample as well as the continuous Turner chlorophyll reading at the time the sample is collected are recorded.

2. Preservation, Transportation and Storage

Samples are preserved, stored, and transported according to the requirements specified in the analysis procedures listed in Table 3. EMP procedures are listed in Table 5.

Table 5: Requirements for sample containers, preservation methods and holding times (EPA, Standard Methods) used for processing discrete samples:

Sample Parameter	**Preservation**	**Transportation Container**	**Maximum Holding Time**	**Disposal Custody**
Chloride	4^{o}C unfiltered	Polyethylene Bottles	28 days	Bryte Laboratory
Silica	4^{o}C unfiltered	Polyethylene Bottles	28 days	Bryte Laboratory
Standard Minerals	0.45 m filtered	Polyethylene Bottles	6 month	Bryte Laboratory
Standard Nutrient	4^{o}C unfiltered Freeze unfiltered	Polyethylene Bottles	28 days	Bryte Laboratory
Suspended Solids	4^{o}C unfiltered	Polyethylene Bottles	7 days	Bryte Laboratory
Volatile Suspended Solids	4^{o}C unfiltered	Polyethylene Bottles	7 days	Bryte Laboratory
Chlorophyll	Frozen	Manila envelope	28 days	Bryte Laboratory
Phytoplankton	2 mL Lugols solution	Glass	Preserved	Archived
Zooplankton	5% Formalin w/Rose Bengal dye	Glass or Polyethylene Bottles	Preserved	DFG
Benthos	10% buffered formalin w/Rose Bengal dye	Polyethylene Bottles	Preserved	M&A Branch

3. Laboratory Analysis

Grab samples are sent to the DWR Bryte Chemical Laboratory (“Bryte Lab,” Bill Nickels, Director) for chemical and chlorophyll analysis. Bryte Lab is located in West Sacramento and organized within the DWR Division of Planning and Local Assistance. This service laboratory was established in 1951 and provides chemical analyses, quality assurance, and related technical services for monitoring and evaluating water quality to programs throughout DWR and to other State agencies. The Laboratory has maintained certification by the Environmental Protection Agency and the California Department of Health Services for water analysis since 1978. Phytoplankton composition and abundance is assessed microscopically by ESO staff. A contract laboratory, Hydrozoology lab, assesses benthos composition and abundance.

4. Quality Assuarance and Quality Control (QA/QC)

a) Calibration Procedures and Frequency: Procedures have been developed for routine testing, maintenance and calibration of the equipment (Table 6). Some of these procedures are currently undergoing revision. Instruments are calibrated to comply with manufacturers or laboratory specifications before and after the sampling run. If a post-calibration indicates significant drift has occurred during the run, data collected during the run are flagged as questionable. An “Instrument Maintenance, Calibration and Repair Log” is maintained for each instrument documenting its condition, scheduled periodic services, the date, and the individual performing the calibration. Along with these procedures an Instrument Comparison Data sheet has been developed to help ensure validation of the continuous monitoring equipment.

Table 6: Instrument Calibration Procedures and Frequency:

Instrument	Calibration	Calibration Schedule	Service & Maintenance Schedule
YSI telethermometer	ASTM Thermometer	Pre/Post Sampling Run	Every 3 months (As needed)
Beckman Conductivity Bridge	Bryte Lab EC Standards	Pre/Post Sampling Run	Every 3 months (As needed)
Hach 2100A Turbidimeter	VWR Turbidimeter Standards	Pre/Post Sampling Run	Every 3 months (As needed)
Turner Fluorometer	Rhodamine B – Bryte Lab	Once a month (As needed)	Every 3 months (As needed)
Turner Nephelometer	Formazin – Bryte Lab	Once a month (As needed)	Every 3 months (As needed)
Vertical Seabird CTD Unit			
1. Dissolved Oxygen Probe	Manufacturer's Specifications	Verification check at each station (using other instruments)	Every 3 months (As needed)
2. Electrical Conductivity Probe	Manufacturer's Specifications	Verification check at each station (using other instruments)	Every 3 months (As needed)
3. Temperature Probe	Manufacturer's Specifications	Verification check at each station (using other instruments)	Every 3 months (As needed)
4. Optical Back Scatterance	Manufacturer's Specifications		Every 3 months (As needed)
5. Depth	Manufacturer's Specifications		Every 3 months (As needed)
Horizontal Seabird CTD Unit			
1. Dissolved Oxygen Probe	Manufacturer's Specifications	Verification check at each station (using other instruments)	Every 3 months (As needed)
2. Electrical Conductivity Probe	Manufacturer's Specifications	Verification check at each station (using other instruments)	Every 3 months (As needed)
3. Temperature Probe	Manufacturer's Specifications	Verification check at each station (using other instruments)	Every 3 months (As needed)
Schneider RM25C	Wt, EC, pH, DO, air temp, SRI, WS, WD	Once a month (As needed)	Every 3 months (As needed)
Data Logger Ocean Data Equipment (ODE)		Checked Daily	Once a year (As needed)
EM100	EC, ph, do, wt	Once a month (As needed)	Every 3 months (As needed)

b) Sampling QA/QC:
Accuracy: The maximum deviation allowed for instrument calibration is 3 percent.
Precision: Each instrument is calibrated as specified above. Also, replicate samples are used to assess precision associated with the laboratory and the field collection process. One chlorophyll sample per day is duplicated, on a rotating basis. Also one chemical sample per day is of a larger volume of sample, (one quart, rather than the pint) for QA/QC testing (Table 2 e).
Completeness: Each sample is collected monthly unless the crew is physically unable to reach or sample the site.

c) Analysis QA/QC: All sampling procedures in this program comply with Standard Methods. Samples conducted by Bryte Laboratory also comply with Standard Methods or EPA Methods.
Representativeness: Sampling sites have been chosen to represent a wide area of the Bay-Delta and major tributaries. The majority of sites have been sampled regularly for more than 30 years.
Comparability: Information collected from discrete samples can be compared with other data collected by Bryte Laboratory, bench instrument readings, horizontal and vertical SeaBird readings, and land based continuous monitoring sites.
Credibility: The accuracy and comparability of the samples lends credibility to the data collected.
Relevancy: A long-term database enables staff to document trends over time that would not otherwise be apparent. The data collected are considered necessary to determine compliance with SWRCB Water Right Decisions.
Clarity: Each datum point will give a clear picture of that constituent at the time sampled, within that body of water. With the advent of relational databases, the clarity of trends will become readily apparent.
Consistency: Since 1975, similar methodologies have been used to collect the data. A cross-calibration study comparing a new chlorophyll analysis method with the method used through 1997 is currently under way.

d) Legal Defensibility: The information provided by this program is supported by more than twenty-five years of historical data and scientific expertise.

III. DATA REDUCTION, ANALYSIS AND REPORTING

Data collected by the IEP EMP currently spans a thirty-two year time period (from 1968 to 2000). The responsibility for data reduction, storage, analysis and reporting activities is distributed to staff within DWR-ESO and DFG. Deliverables for this program include reports to the Board summarizing annual water quality, phytoplankton, zooplankton, and benthic data and relating the data to the historical database. Updates of ongoing compliance monitoring and results of special studies associated with this monitoring program are also included in the IEP newsletter. Data reduction and analysis activities rely on several assumptions. The primary assumptions are: (1) the data collected is sufficiently accurate and precise evaluate trends; (2) sample replication is adequate to indicate data patterns; (3) the number of stations sampled is adequate; (4) the monthly sampling frequency is sufficient, and, (5) the proper parameters are being sampled to show the effects of DWR and USBR exports on the ecology of the Delta.

A. Data bases

The data storage and recording components of the IEP EMP are currently under revision or in transition from older to newer procedures due to the implementation of the new comprehensive, on-line Bay-Delta and Tributaries Database (IEP BDTDB; http://sarabande.water.ca.gov:8000/~bdtdb/) as well as new internal DWR data entry and storage systems. After this transition, data from the discrete sampling program will be edited, stored and available to users in the Bay-Delta and Tributaries Database as soon as possible after the completion of each sampling run. The water quality component of this new online IEP relational database will contain validated data from 1975 through the present. Currently, a historical database for each of the monitoring elements within this program through 1995 with accompanying meta-data information is still available on-line at http://iep.water.ca.gov/wqdata/.

After completion of all new data base modules, data handling will proceed as follows: discrete water chemistry and chlorophyll data is entered and managed in the DWR Field and Laboratory Information Management System (FLIMS) before being transferred into the internal DWR Water Data Library (WDL) and from there into the new IEP Bay-Delta and Tributaries Database. FLIMS was designed to provide a “cradle to grave” electronic path for water and soil grab sample data within DWR. It consists of a field and various of lab modules. The FLIMS Field Module streamlines the planning and implementation of field sample collection runs and simplifies required paperwork. FLIMS also provides many built-in features that assist in quality assurance/quality control (QA/QC).

Identification and enumeration of phytoplankton, benthic organisms, and zooplankton, as well as chemical determinations and quality assurance/quality control (QA/QC) information should be available within a month after collection once the Bay-Delta and Tributaries Database and transfer pathways between the different data bases are completed. Vertical and horizontal profiles recorded during vessel discrete sampling runs will be available in numerical and graphical display formats within a month of the water quality monitoring run as soon as electronic data transfer modules are completed (currently in progress). Unchecked DO, pH, EC and water temperature data from the multi-parameter monitoring sites is telemetered to Sacramento and is available on a near real-time basis on-line through the California Data Exchange Center (CDEC) database (http://cdec.water.ca.gov/). Multi-parameter monitoring site data are currently checked and processed monthly upon manual retrieval from the field stations. Once the data is processed, it is uploaded to the IEP HEC-DSS Time-Series Data Base accessible at http://iep.water.ca.gov/dss/all/. Several continuously measured parameters are currently not accessible through the internet. These parameters are wind speed, wind direction, solar radiation intensity, and chlorophyll. The unavailable data is currently stored within DWR's Monitoring and Analysis.

B. Data assessment and oversight

1. QA/QC Data Checks

QA/QC data checks are made both while onboard the sampling vessel or van and through the use of the DWR Field and Laboratory Information Management System (FLIMS). Data is checked for inconsistencies and outliers.

Field sheets are produced in the office and taken to the field to be filled out by hand as the data is available. Vertical SeaBird data can be checked for accuracy by reviewing archived data. Data is then keyed into a FLIMS document using a laptop computer. This data is reviewed for accuracy by a person other than the key data entry person.

Data found to be in error in the field is corrected in the field. Data that is passed into the FLIMS data bank can be changed while the data still resides at Bryte Lab. Bryte Lab personnel will do corrections upon direction.

For all data types, chronic or unusual data quality problems are reported to the Section Chief and resolved as necessary through meetings of the Data Management Work Groups and assignments to appropriate staff. In addition, suspect data are tested statistically when necessary and removed from the data set when appropriate. Removed or missing data are recorded as such. Invalid data which remains in a data set is noted in the record. Table 7 describes the error checking that is or will be performed for statistical testing, visual graphical inspection for unusual spikes, and comparisons of certain values against valid reference tables comprise important steps in the error checking process used by the Branch.

Table 7: Error Checking Procedures

Data Type	Error Checking Procedure
Discrete Sampling:	
Phytoplankton	Verification of station and organism names against valid lists
Chlorophyll	Verification of station names against valid list; use graphs to check incoming data for suspect values.
Benthos	Verification of station and organism names against valid lists
Water Quality	
Physical Parameters(temperature, salinity, turbidity)	Verification of station names against valid list; use graphs to check incoming data for suspect values.
Nutrients (silica, dissolved inorganic nitrogen, ortho-phosphate)	Verification of station names against valid list; use graphs to check incoming data for suspect values.
Organic Matter	Verification of station names against valid list; use graphs to check incoming data for suspect values.
Chemical (dissolved oxygen)	Verification of station names against valid list; use graphs to check incoming data for suspect values.
Vertical and Horizontal CTD	Program stripping leading and trailing invalid values.
Continuous Multi-parameter Sampling	Graphical checks of incoming data for suspect values. Unusual spikes are also compared to other parameters for possible explanation.

2. Field and Laboratory Performance and Systems Audit

In the past, a separate Division within DWR has audited the field systems and protocols. A team of three people from the Division of Local Assistance visited sites where field operations take place, including the sampling vessels and van. Audit criteria used are contained in the Training Manual for Quality Assurance/Quality Control, written by DWR, Division of Local Assistance, QA/QC Program. A report was produced that documented the performance of all the field operations within DWR. Bryte Laboratory, being an accredited lab undergoes regular accreditation examination.

3. Corrective Action

The Program Manager oversees any necessary corrective action. The staff then carries out the actions as directed and provides verification to the Program Manager and the auditing body that the action is sufficient to correct any problems previously encountered.

IV. PROJECT ORGANIZATION AND RESPONSIBILITIES

Table 8: Project organization

Element	**Lead Individual**	**Address**	**Phone**	**Email**
Water Quality	Steve Hayes	DWR, 3251 S Street, Rm. C-29, Sacramento, CA 95816	(916) 227-0439	shayes@water.ca.gov
Phytoplankton	Casey Ralston	DWR, 3251 S Street, Rm. C-27, Sacramento, CA 95816	(916) 227-7551	cralston@water.ca.gov
Benthos	Cindy Messer	DWR, 3251 S Street, Rm. C23, Sacramento, CA 95816	(916) 227-7545	cmesser@water.ca.gov
Zooplankton	James Orsi, DFG	4001 N. Wilson Way, Stockton Ca. 95205	(209) 942-6087	jorsi@dfg.ca.gov
Multi-parameter	Hank Gebhard	DWR, 3251 S Street, Rm. C31a, Sacramento, CA 95816	(916) 227-7542	hgebhard@water.ca.gov
Data Management	Kitty Triboli	DWR, 3251 S Street, Rm. A16, Sacramento, CA 95816	(916) 227-0435	ktriboli@water.ca.gov

V. PERSONNEL TRAINING

Senior staff members train new employees in field and lab techniques. New employees are also required to undergo training specified in the following training and safety manuals:

- IEP Estuarine Monitoring Safety Plan (1996)
- San Carlo Boat Safety Equipment and Procedures (2000)
- Chemical Hygiene Plan, Compliance Monitoring and Analysis Branch (1998)
- General Lab Safety Procedures (2000)
- Hearing Conservation Plan (1996)

Records on training are kept in the ESO Monitoring and Analysis Branch. All safety training manuals are available upon request from the program's safety coordinator Scott Waller, (916) 227-0433.

VI. DETAILS OF ON-BOARD PROCEDURES

This section describes procedures carried out on the San Carlos or in the lab van. Analysis protocols used by Bryte lab are referenced in Table 3 and available upon request.

A. Secchi Disc Depth:

The Secchi disc shall be used in the shade only and without sunglasses. The Secchi rod is marked every 4 centimeters. The top surface of the Secchi disc is painted black and white.

Procedures:

Lower the disc into the water in the shade until the Secchi disc is no longer visible. Raise the Secchi disc up it just becomes visible and read the top of the rod at the water level. Slightly rotate the disc for better resolution. Equate the centimeters by counting each mark from the water surface to the bottom of the secchi and multiply by 4 to reach the final reading. Take into consideration if the water is between marks and calculate into the final figure.

Conduct all Secchi disc readings while the boat is holding its position, so that one can maintain balance and not fall overboard.

B. Dissolved Oxygen:

Modified Winkler Method: The iodometric test is the most precise and reliable titrimetric procedure for DO analysis. It is based on the addition of divalent manganese solution, followed by strong alkali, to the sample in a glass-stoppered bottle. DO rapidly oxidizes an equivalent amount of the dispersed divalent manganous hydroxide precipitate to hydroxides of higher valency states. In the presence of iodide ions in an acidic solution, the oxidized manganese reverts to the divalent state, with the liberation of iodine equivalent to the original DO content. The iodine is then titrated with a standard solution of thiosulfate. The titration end point can be detected visually, with a starch indicator. Experienced analysts can maintain a precision of +/- 50 µg/L.

Procedures:

Sample collection:

Collect samples very carefully. Methods of sampling are highly dependent on source to be sampled and, to a certain extent, on method of analysis. Do not let sample remain in contact with air or be agitated, because either condition causes a change in its gaseous content. Collect surface water samples in narrow-mouth glass-stoppered BOD bottles of 300mL capacity with tapered and pointed ground-glass stoppers and flared mouths. Avoid entraining or dissolving atmospheric oxygen. In sampling from a line under pressure, attach a rubber tube to the tap and extend to bottom of bottle. Let bottle overflow two or three times its volume and replace stopper so that no air bubbles are entrained.

Sample analysis:

Reagents (Dry reagents: Hach powder pillows):
a. Manganous sulfate
b. Alkali-iodide-azide
c. Sulfamic acid
d. Starch
e. Sodium thiosulfate
f. Potassium bi-iodate

To the sample, add manganous sulfate, followed by alkali-iodide-azide. Stopper carefully to exclude air bubbles and mix by inverting bottle a few times. When precipitate has settled suffieciently (to approximately half the bottle volume) to leave clear supernate above the manganese hydroxide floc, shake the bottle a second time and allow the floc to settle a second time. Add the sulfamic acid. Restopper and mix by inverting several times until dissolution is complete. Titrate 200 mL of sample. Titrate to a pale straw color. Add a few drops of starch solution and continue titration to first disappearance of blue color. The amount of reagent needed corresponds to the D.O. concentration in the sample.

Overrun:

If the end point is overrun, back-titrate with 10 mls of sample, and retitrate. Ten mls is 5% of 200. The end point with 10 mls of sample added is divide by 1.05. Calculate the end point with 20 mls of sample added... divide by 1.1, because 20 mls is 10%

D.O. Sodium Thiosulfate correction factor: To find this factor (determined on the first day of the run), add alkali-iodide-azide and sulfamic acid to 100 or 200 ml of distilled water. Mix well, then add 10 mls of potassium bi-iodate. Titrate to clear end point. Divide the 10 ml of potassium bi-iodate by the end point of sodium thiosulfate:

$$10 \text{ mls } KIO_3 \div 10 \text{ mls of sodium thiosulfate} = \text{ factor of } 1$$

C. Hach Turbidity

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, along with plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction of flux level through the sample.

Nephelometric Method:

1. *Principle:* This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light, the higher the turbidity. Formazin polymer is used as the primary standard reference suspension.

2. *Interference*: Turbidity can be determined for any water sample that is free of debris and rapidly settling coarse sediment. Dirty glassware and the presence of air bubbles give false results.

3. *Sample cells*: Use sample cells or tubes of clear, colorless glass or plastic. Keep cells scrupulously clean, both inside and out, and discard if scratched or etched. Never handle them where the instrument's light beam will strike them. Use tubes with sufficient extra length, or with a protective case, so that they may be handled properly. Fill cells with samples and standards that have been agitated thoroughly and allow sufficient time for bubbles to escape.

Clean sample cells by thoroughly washing with laboratory soap inside and out followed by multiple rinses with distilled or deionized water. Let air dry. Handle sample cells only by the top to avoid dirt and fingerprints within the light path.

4. *Preservation*: Determine turbidity as soon as possible after the sample is taken to prevent temperature change and particle flocculation and sedimentation from changing the sample characteristics. Gently agitate all samples before examination to ensure a representative measurement. Sample preservation is not practical; begin analysis promptly. Refrigerate or cool to 4^{o} C and hold samples in the dark to minimize microbiological decomposition of solids, if storage is required.

Hach Turbidimeters must be calibrated at the beginning of each day's run. It is wise to recheck instrument drift with a 20 standard before each water sample. The instrument is read on the 100 scale. If the sample is over 35, dilute the sample with deionized water, agitate and reread.

D. Chorophyll *a* sample collection and preparation:

Discrete chlorophyll samples are collected and filtered on the San Carlos or the lab van. The filters are then taken to Brite lab for spectrophotometric analysis.

Procedures:

Apparatus:

a. Three port vacuum manifold, with one port closed
b. Two plastic filter funnels, Gelman or equivalent
c. Vacuum system with two one-liter flasks (waste containers)
d. Glass fiber filters e.g. Whatman or Gelman (47 mm), 1.0

Note: Do not filter the samples in direct sunlight. Sunlight destroys chlorophyll. Do not filter a sample containing any leaf or clumps of duck weed. Such a sample would result in an excessively high chlorophyll measurement.

1. Collect sample with a clean Van Dorn, Kemmerer, or pump sampler.

2. Place two 47 mm diameter glass fiber filter discs (Gelman Type AE) in the filtering apparatus. The upper filter should have the "grid patterned" side up. The bottom filter is used as an indicator that the complete sample volume was sieved through the top filter. If the top filter was misaligned, there will be an aurora of color on the bottom filter. You then know you must discard the top filter, and resample. The bottom filter also serves to maintain suction (the vacuum pump is to be left on while the sample filter is removed) so that the top (sample) filter will be as dry as possible. This state of dryness is desirable in order to maintain the 90% ratio of acetone to water in the extracting solvent.

3. The preferred sample volume is 1000mls. If the water is too turbid and it is not feasible to filter the full 1000mls within 10 minutes, a smaller volume will then be filtered. If the volume filtered falls to 400ml, then a duplicate sample must be taken.

4. Filter at less than ½ atmosphere pressure, or ten inches of mercury. When the sample is nearly filtered, add about 5 ml of freshly shaken $MgCo_3$ suspension (about 5 g $MgCo_3$ /L and about 20 ml of distilled water) to the sample remaining in the filtering apparatus.

5. Fold each filter disc in half with the filtered contents inward and place in a small coin envelope. Make sure the filters do not overlap in the envelope.

6. The sample envelope should be labeled with a FLIMS label affixed. Add time and **volume** information to the label. Mark this information on the envelope in lead pencil only, in that ink may run and add color to the sample and interfere with analysis.

7. Place the envelopes in the freezer, or in a container of dry ice. If the samples are first placed on the dry ice, be sure the envelopes are directly in contact with the dry ice.

8. Each sampling day, one replicate sample will be taken. The parent sample is designated on the FLIMS test request sheets, on the field sheets, and on the replicate sample form. It is of great importance that the parent sample and the replicate are duplicates. Care should be taken that the sample is well mixed, measured exactly, and all sample delivered into the filtering funnel.

The data gathered from the parent sample should be recorded (repeated) for that replicate sample on the FLIMS field sheet on the lap top computer.

9. Clean filtering apparatus with distilled water.

APPENDIX 3